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EINSTEIN'S PRINCIPLE OF RELATIVITY AND ITS BEARING UPON PHYSICS.*

BY

JOSEPH S. AMES, Ph.D., LL.D.

Director of Physical Laboratory, The Johns Hopkins University, Baltimore, Md.

When I received the invitation to address The Franklin Institute on the subject of Einstein's Theory of Relativity, I hesitated for many days before accepting it; and even now, with my thoughts in order and my words in mind, I am not convinced that I can accomplish what both you and I are hoping I can do: make the work of Einstein clear to a group of people who are not specifically physicists or mathematicians. If you were the latter, that is, if you had devoted yourself recently for a number of years to an intensive study of physics and mathematics, I am certain that I could explain to you the main features of Einstein's work—by at least a month of class lectures. But what can I do in one hour? The best I can really hope to do is to explain the main outline of Einstein's contribution to our philosophy, emphasizing only a few, very few, points.

The underlying principles of Einstein's theory are exceedingly simple; *they* may be made clear; but the way in which they are used is not as simple; to understand this requires not alone

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* Presented at the Stated Meeting of the Institute held Wednesday, October 20, 1920.

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an acquaintance with many physical phenomena but also an appreciation, at least, of the power of mathematics. I must either take this as granted or ask you to believe me.

The purpose of a lecture such as this is not, I am assuming, to convince you that Einstein is right in his method and conclusions, nor to carry you step by step through his reasoning, but, rather, to state the problems he had in mind and to indicate how he attacked them. At the very beginning I must state two facts which may not be known to you all. The first is that, although the deduction of a new law of gravitation by Einstein has appealed to the imagination of the public, this is only an incidental feature in Einstein's work; other consequences are really of much greater importance, even to the world at large. The second is that it is not correct to say that Einstein has proposed a " theory " of anything, in the sense of giving a picture of any mechanism. We speak properly of the " corpuscular " theory of light, a theory advanced by Sir Isaac Newton that light as a sensation is due to streams of minute particles which leave the luminous body and finally, after passing through space or portions of matter, enter the eye and affect the retina. Or we may speak of the " kinetic " theory of matter, meaning by that that we try to account for many of the properties of matter by attributing to its minute moving parts, its atoms and molecules, the same characteristics which we find by experience are common to large portions of matter, such as billiard balls or croquet balls. Thus, in using the word " theory " of any phenomenon we ordinarily mean that we are proposing a picture or description of it in terms of more familiar or more simple facts. Now Einstein does not in any sense give us a picture of gravitation, nor does he attempt to describe it in terms of other phenomena. As a matter of fact, in the course of the development of his concept of nature, he finds a mathematical statement of the facts of gravitation as observed by us.

Let us see what these facts are, and incidentally discuss the method used by Newton in his great Principia. Newton and Galileo before him studied with the greatest care the simplest cases of motion and matter, such as the impact of one body against another, a body falling towards the earth or thrown up away from the earth, an arrow or bolt shot from a cross-bow, etc. Both these great philosophers sought to express their observations in simple form, and to formulate certain laws or postulates, which, if true, would account for their observations. In this connection Newton found it convenient to introduce the use of the word " force " and give it a precise meaning, the line of thought being as follows: He and Galileo both expressed their first law of motion by saying that, if a material body is in motion and is far removed from all other bodies, its state of motion will not change. Naturally, this cannot be proved by any experiment or observation of ours; it is a question of belief, a portion of a creed. Then, if we observe that the motion of a body is changing, we use the expression, following Newton, " there is a force acting on " the body. This is, so far, nothing but a form of words, a description of the fact that the motion is changing. Thus, if we see an apple falling from a tree, we note that, as it falls, it goes faster and faster, its motion is changing each instant; we say there is a force acting on it, and speak of the " force of gravity." We are not attributing any property to the apple or to the earth; we are simply using a special word to describe an observed fact. Or again, if we tie a stone to one end of a string and, holding the other end in our hands, make the stone whirl in a circle, we see that the motion of the stone is changing each instant, its direction is altered continuously; we say that there is a force acting on it, the force of the tension of the string. Similarly, when the motion of the moon is considered, it is observed to be in a nearly circular path around the earth, its direction is changing continuously, here again there is the action of a force. Newton proceeded further, and in terms of the mass of the body, that is its quantity of matter, defined the force exactly, giving it a definite mathematical value. To Newton it was evident that the force acting on the falling apple and that acting on the moon were both illustrations of a common phenomenon; both were associated with the earth. He propounded the idea that between any two material bodies in the Universe there was a force acting, that is, if they were first held at rest and then let go, they would approach one another with a greater and greater speed. As a matter of fact, the earth does rise so as to meet the falling apple and the moon is continuously falling in towards the earth, but only so far as to keep in its circular orbit. This is Newton's principle of Universal Gravitation, or at least part of it. The other part, that of stating in mathematical language the law of gravitation immediately engaged Newton's attention. He required as a starting point exact knowledge of the facts of observation; that is, of the motion of the falling apple, of the moon and of the planets in the solar system, for evidently these last had their motion subject to this desired law of gravitation. He needed to know how rapidly the speed of the apple changed, whether other falling bodies of different substances and different weights fell in exactly the same way an apple did; and here a knowledge of Galileo's famous experiments on the fall of different bodies from the top of the Leaning Tower of Pisa and on pendulums having different bobs helped him, indicating that so far as gravity alone was concerned all bodies, of varying sizes and material, had the same motion as they fell to the earth, that is, the acceleration of their velocities was the same. He also wished to know the size of the moon's orbit and its period of revolution, the nature of the orbits of the planets, how rapidly they moved and their periods of revolution around the sun. Fortunately he had at his disposal the knowledge required. So far as the planets were concerned Kepler had discovered by many years' patient study of Tycho Brahe's astronomical observations certain facts, known as Kepler's laws. Newton then tried to imagine some simple statement applicable to the Universe such that, if it were true, the known facts of observation could be deduced by mathematical processes. He succeeded in proving that, if there is a force of attraction between two particles of matter of masses m_1 and m_2 at a distance of r apart which is proportional to the product of their masses and inversely to the square of their distance, *i.e.*, to $m_1\ m_2/r^2$, then all the observed phenomena so far as known could be deduced. This is Newton's law of universal gravitation: it is not a theory, there is no correlation with other natural phenomena, it is simply an attempt, and a most successful one, to express a countless number of facts in a simple form. The experience of over one hundred years, all the predictions of astronomy so amply verified, have confirmed our belief in the accuracy of Newton's law. There is, however, one feature of universal gravitation about which there was no knowledge in Newton's day nor even in our own till most recently. This is a question which might very easily be asked; is the law of gravitation different for bodies moving slowly and those moving rapidly? The greatest velocity known is that of light, about 186,000 miles per second; and in comparison with this the velocities of the planets may in general be called small. So it is perfectly possible that Newton's law is a statement of fact for bodies moving slowly, but requires modification in case they are moving rapidly. Such now appears to be the case; we have knowledge of the action of gravitation in the case of great velocities; and Newton's law does not express the facts. Moreover, Einstein has proposed a law which does correspond in a wonderful manner with these and all known facts. Two points in this connection may well be emphasized. Einstein has not disproved Newton's law, he has simply described the limitations within which it holds. Of course, if any one were to claim that Newton's law tells the whole truth about gravitation, then it would be fair to say that Einstein had disproved this claim. Again, Einstein did not obtain his law by trying to discover a mathematical form for known facts, nor did he try to make slight modifications in Newton's law so as to make it fit better with new facts. What he did was to take a general view of all natural phenomena, as revealed to us by our observations and measurements, and then to formulate certain general principles which appealed to his philosophy, principles so simple that they admitted of proof or disproof only by drawing conclusions from them and comparing them with direct observations. Among these deductions was a new statement of a law of gravitation. It cannot be expressed in a simple manner, unless we make certain limitations upon our conditions. In particular, if we wish to apply the law to cases where the velocity is small, it takes the form proposed by Newton.

I do not believe that any one here is interested in knowing the exact statement of Einstein's law nor in hearing details of the facts of which it is the expression. What every one wishes to know is the method followed by Einstein: what were the general principles of nature proposed by him, how did he come to make them and how did he draw conclusions from them. I shall do my best to explain these matters to you, and I hope I can make you share in the wonder and admiration I feel in thinking of the genius and ability so clearly shown by Einstein in all his work.

When we consider any phenomenon of nature, for instance, a falling body, we realize that before we can state any facts about it—facts of importance—we must be able to measure, or give numbers to, the various quantities concerned. We must know how fast it is moving at any instant and how much this velocity changes during a certain definite interval of fall; or else we can start by making some assumption in regard to the motion and, after deducing the consequences and comparing them with observations, decide whether our assumption is right or wrong. In either case we need to be able to give numbers to the quantities observed. Two fundamental quantities are intervals of length and intervals of time. Every one knows how we measure them in practice. To measure a length, for instance, that of a table, we select first of all a measuring rod, which, as a rule, is divided and marked with divisions equally spaced, and then by applying the rod along the edge of the table, marking its ends, replacing it, etc., we finally can obtain the length desired. If living in America or England, we would use ordinarily—not in a scientific laboratory—a yard-stick subdivided into fractions of an inch; if we were working in a laboratory or were living anywhere else in the world, we would use a metre-rod subdivided in centimetres and millimetres. The method used would be the same. This is called the method of superposition, and it involves the definition of what we mean when we use the words "two lengths are equal," namely, we say two lengths are the same if the two intervals of which we are speaking can be superimposed. In other words, to measure a length we adopt some unit and find how many times it is contained in the length. But when we consider an interval of time and the means we use in giving it a number, we recognize at once that a different method is required. To propose the selection of a unit of time and to see how many times it is contained in the interval in question is to talk nonsense; we cannot put our hands on a unit of time. and we have nothing to compare it with, for when time passes it is gone forever. What we actually do, as you all know, is to count the seconds or minutes elapsing in any time interval by looking at a watch or a clock. This practice is based upon our belief that the time intervals between two ticks or beats of a clock are the same. Of course, we can never *prove* that this is true; for if I were to maintain that the pendulum of a clock did not swing regularly, how could you disprove my assertion? Certainly not by comparing it with another pendulum, because I might say that it also was not swinging regularly. As a matter of fact, our method involves the definition of what we mean by the words "equal intervals" of time. It is a perfectly good method, as a hundred years of observation have shown. In this connection I must also call to your attention the idea involved in saying that two events are simultaneous. Suppose, for instance, two men a mile apart raise their right hands, how do I decide if they do it simultaneously? I might stand near one of them, in some position so that I can see both, and might then watch them carefully. But it takes time for light to come from the distant man to my eye; and so, when they are apparently raising their hands simultaneously, they are not; the man at a distance is slightly ahead of the other. This method can be remedied if I station myself half way between the two men and then by means of mirrors arrange so that I can watch both men at the same time. Then I can decide if their motions are simultaneous. This conviction of mine depends upon my belief that the velocity of light is the same in both directions and that it is a constant unchanging quantity. Einstein, in substance, proposes as a method of defining equal intervals of time, not the selection of pendulum swings, but the use of light signals. His definition of equal intervals is the times required for light to traverse equal lengths. This is really a better definition.

We are now ready for the first step in Einstein's process of thought. In discussing, so far, lengths and intervals of time we, as a rule, think of the length to be measured and the clock at which we are looking as being at rest with reference to ourselves. The question may not be so simple if they are moving. For instance, if a railway train is in motion, how would we measure the length of one of its cars? We would station several observers along the tracks; then, as the train passed, two of these might be so placed that they could note *simultaneously* the two ends of the car by making marks on the ground near the track; and later by means of our measuring rod we would measure the distance between the two marks. Another observer travelling on the train and having a rod the same as the others are using on the ground could also measure the length of the car. Would the two measurements give the same value for the length? Einstein raised this question and showed that, before we could answer it, it was necessary to be very definite as to what we meant by our words and as to what we believed in regard to observations made of stationary and of moving objects. One of the simplest cases familiar to us of observations of moving bodies is furnished by two trains moving on parallel tracks. To begin with, if a person were in a train moving at a uniform rate, he would be entirely unconscious of the motion if he didn't look out of the window; for the only thing that in practice makes a traveller know that he is moving is the almost constant occurrence of slight irregularities in the motion and certain sounds. Now, if our two trains are moving uniformly, but one more rapidly than the other, when one passes the other, an observer in one train looking out of the window at the other cannot decide whether he is at rest and the other train moving, or he is moving and the other train is at rest, or both of them are moving. How often has it happened to each one of us, when we have been sitting in a train in a station watching another train on the next track, that, if this train slowly moved past the window, we were uncertain as to which train was actually moving, our own or the other? When one train moves by another, there is what is called relative motion between them; and every one is familiar with many illustrations of such motion. An observer on either body, so long as the relative motion is uniform, not jerky, cannot, by simply looking at the other, decide anything as to its own motion; he may be at rest, he may be moving slowly or rapidly. All he knows is that there is *relative* motion. In regard to absolute motion, *i.e.*, his own motion, he knows nothing. Einstein generalized this visual experience of ours by stating, in the form of what mathematicians or logicians call a "postulate," that in the case of uniform relative motion, such as our two trains, it is impossible for an observer moving with either body to decide about his own motion by any means at all, he may look at the other body, or he may try any means, using sound, magnetism, or electricity. Expressed slightly differently this says that if two observers are attached to two systems which have uniform relative velocity the phenomena and laws of nature will be the same for them both. This postulate appears to every one, I am sure, as perfectly reasonable and in accord with his own experiences. It is one of those statements which cannot be proved directly, however: it is too general. We must draw as many conclusions from it as possible and see if they are confirmed by experience.

If an observer on a moving train wished to make measurements of time, or to decide whether certain events are simultaneous, he would use light signals. But will the velocity of light as observed by him be the same as it would be if the train were at rest? Here we must not fall into a logical trap. We have agreed, following Einstein, to use light in our method of defining intervals of time; so we shall have no way of answering the question directly. But indirectly there is evidence that it is the same for an observer at rest or on the moving train. Of course, the observer whom we speak of as moving might say that he was at rest and we were moving. All that is known to him or to us is that there is relative motion. So Einstein makes as his second postulate; the velocity of light, no matter how observed, or what its source, is always the same. Of course, in this he means, as he clearly says, the velocity of light in a vacuum; but the presence of the air makes no difference requiring attention. (It must be added that this postulate requires modification when we deal with an intense gravitational field.)

These two postulates may appear to you very simple and self-evident; almost of trivial importance. But their consequences are by no means so. They may, in fact, be fairly called revolutionary to many of our preconceived ideas.

It is now a simple matter to answer the question which was asked some time ago, that concerning the length of a railway car as measured by a man in the car or by observers along the track. It may be proved that to the latter the length is slightly less than to the former. This difference in length is extremely minute, too small for measurement in the case of any railway train, but it is definite. If there is a yard stick lying lengthwise in a car of each of our two trains which are in relative motion, either observer looking first at his own stick and then at the other would say that the one which appears to him to be moving looks shorter than the other. So the length of a rod has no absolute meaning, it all depends upon whether the man looking at it or measuring it is at rest with reference to it or not. If, however, the yard sticks are lying across the cars or are standing on end, the appearance of either rod is the same to both observers. Thus a body which appeared spherical to one would look like an ellipsoid to the other. You note that I do not say that the length or shape is actually changed; all I am saying is that bodies look differently and give different measurements to people who are at rest with reference to them and to people who are not. I must not speak of absolute or real rest, or motion, or lengths, but only of facts of observation.

Another question in regard to systems having relative motion can also now be answered. Suppose there is a pendulum clock on one train and suppose there is some movement going on, for instance, suppose a man is writing or working a typewriter, how will they appear to a man on the other train? It is proved easily that the pendulum will appear to swing more slowly, and the man who is writing will apparently be working at his task more leisurely than would be the case if the observer were on the first train. A general statement is that if there is relative motion between two systems, all bodies in one system will appear contracted in the direction of motion to an observer in the other system, when he compares his impressions with those he has on looking at similar bodies in his own system; and all time intervals in one system appear to an observer in the other to be prolonged. It follows, too, that two events which appear to one observer to be simultaneous would not appear so to the other. Therefore, one sees how careful one must be in describing things. We have, thus, another illustration of the same object appearing differently to different people, the case of the two sides of the shield. If we had here on the earth a large body which to a man on the earth appeared spherical, and, if a man were flying over the earth in an imaginary airplane at the imaginary speed of 150,000 miles per second, he would say, in looking at the body, that it was like an egg standing on its end. If he were to see men walking about he would wonder how they could walk so slowly and not fall over. The really important fact to note is, as said before, that we cannot speak of the absolute or real length of a body, or the real value of an interval of time. The words have no meaning. Whenever any measurement is given we must always state something about the observer: is he moving with the thing measured, or is he not?

I could fill all the rest of my hour in telling you of the many striking consequences of a realization of this fact. Einstein called attention to many of them, but they are of interest in the main to physicists only. It is important to add that every deduction so far made which is capable of experimental investigation has been verified.

As I have been careful to note, Einstein's early work referred to bodies whose relative motion is uniform. Now in nature nothing is rarer than uniform motion; all the motions we have ever observed have been varying, or at the best have been uniform for only short periods. Therefore, it was very natural for Einstein to consider if there were any general statements which could be made in regard to two systems whose relative motion was non-uniform. He did convince himself that there were such statements, and these additional postulates form the basis of many deductions, among them the law of gravitation. Before stating these postulates, however, I must take a few minutes for the explanation of some simple mathematical methods. Einstein made the perfectly obvious, but most important, remark that all of our knowledge of nature is in reality nothing but the perception of a series of coincidences. If I say that the temperature of this room is 70° F., what I mean is that I have a Fahrenheit thermometer, and on looking at it I observe that the end of the mercury column coincides with the 70th degree division. If I study a falling body, all my knowledge comes from rays of light coinciding with the retina of my eye. Therefore, all the laws of nature which we have deduced from our experiences, or which we may deduce in the future, must be statements concerning coincidences. To describe in mathematical language any event requires an expression of two things: first, the location of the event in space, *i.e.*, where it takes place, and secondly, the instant of time when it occurs. We have an extremely simple method of doing both of these. Suppose I wished to describe to some one the exact position of the corner of this desk with reference to this hall. I could measure its distance above the floor and its distances from two of the walls meeting in a corner; a knowledge of these three lengths definitely locates the corner. The process you see is this. I select three planes—the floor and two walls in this case—which are mutually perpendicular, and I measure the distances of the point in question from these three planes. These lengths are called the space coördinates of the point with reference to the three planes, or with reference to the three lines, or axes, in which these planes intersect. In this manner, using any reference system we wish to select, we can describe the location of any event. Naturally, if I use a different reference system, I shall have different coördinates. To describe the instant of time requires simply the adoption of some standard clock. The reading of this will give us the time coördinate of the event. The description of the event requires, therefore, the determination of four coördinates. If we are observing any phenomenon, for instance a falling body, it is clear, I suppose, to all that the description of the motion will depend upon the reference system of coördinate planes or axes adopted. Thus, if we choose our axes fixed on the earth, one vertical, one North and South, and the third East and West, we would describe the motion as parallel to the vertical axis. Suppose, however, we are in a moving railway car and choose our axes as follows: one perpendicular to the floor, one along the car and one across it; then, if through the window we observed the falling body, for instance a raindrop, we would describe its motion as being oblique, not vertical; it is not parallel to the edge of the window. Again, suppose we are in an airplane and choose our axes fixed in it, then, if while the machine is manœuvring we observe a falling raindrop, we would say that it had an apparently very complicated motion. Thus our description of any phenomenon will vary with the set of reference axes adopted. But suppose that two events coincide, then it is evident that the statement of this fact is quite independent of our selection of axes. For instance, if a raindrop hits the umbrella of a man who is walking, it is true that the description of the path of the drop as it is falling and of the man while he walks will depend upon whether we are at rest on the earth, or in the moving train or in the airplane; but the statement of the coincidence of the path of the drop and that of the man's umbrella is the same in all cases. Thus the description of a coincidence is independent of our selection of reference axes. We immediately see the importance of Einstein's remark about the laws of nature being simply a formulation of facts about coincidence of events. Since this is the case, the form of any law of nature must be the same for all systems of reference axes. This, as a matter of fact, is Einstein's postulate, what he calls the " Principle of General Relativity."

Among the laws of nature is to be sought the law of gravitation. If we describe the motion of a falling body or of a planet, our description will, as I have explained, depend upon our choice of reference axes; but when we come to generalize our observations and express them in a law—as Newton attempted to do—we can be perfectly sure, in accordance with this principle formulated by Einstein, that its form will be the same no matter what reference system we adopt in order to state the mathematical facts. This statement is applicable to all other laws of nature, not simply to a law for gravitation. We are thus introduced to a mathematical problem, namely the investigation of those mathematical expressions which keep the same form when we use different systems of coördinates. This is a well-developed branch of mathematics, but one which up to the past few years, till in fact Einstein showed its importance in the study of natural phenomena, was comparatively unknown to most students of physics. Recently, however, we have all been obliged to go back to college days and devote strenuous weeks to mathematical study.

Let us now see if we can follow Einstein's mode of thought in investigating gravitation. He knew, of course, that the law stating the facts must have the mathematical properties just described; he knew also that the true law must have such a form that under ordinary conditions it reduced to Newton's because this last expresses most of the known facts so well; but all this didn't help much. He wished to find some general method of describing and comparing phenomena in a space or region where there is no gravitational action with phenomena in a region where there is this action, that is, in what we call a gravitational field.

It is evident that if we were to perform any mechanical experiments near the earth or if they were made near the sun or near the moon, there would be complications owing to gravity; but if we were to be far off in space, away from the solar system, gravitation, as we know it here, would not trouble us. So if we had a space with its reference system of axes attached, as it were, to the "fixed" stars, it would evidently be the simplest one for us to consider. This is called a Galilean space or system. In such a space, since there are no gravitational effects, a body would not "fall" in any direction; if at rest, it would stay at rest without any support; if thrown by anyone, it would move in a straight line. I mean by this that these would be the facts observed by a man who was at rest in the system. Whereas in a gravitational field, that is, in a region where gravity is felt, if a body is let go from rest, an observer at rest will note that it will fall in the direction of the field; if it is thrown in any direction across the field, he will say that it has a curved path, like that of a stone which a boy on the earth throws up in the air. Einstein remarked that we could also secure, if we wished to, a Galilean space upon the earth, or the sun, or anywhere, by a very simple device. Suppose we had a large box, as large as a room, so that an observer might stand inside and perform different experiments, and let this box be dropped from some height so as to fall freely towards the earth. The man inside, if he couldn't see out, would be entirely unconscious of the fact that he was falling and, in fact, of any gravitational sensation. He would not feel himself pulled down, nor, as a matter of fact, do we here on earth. We are conscious rather of being pushed up by the floor on which we are walking; but the man in the box does not have this sensation. So far as he is concerned gravitation does not exist. If he is holding a stone in his hand and simply releases it, it will not fall so far as he knows, it will appear to stay where it is; if he throws the stone in any direction, its path, as he observes it, will be a straight line. So the space in the box is a Galilean one. But if there is a man on the earth, or on a building, who can look into the box, he will say that the stone released from the hand is falling and that the path of the stone when it is thrown is curved; in other words, he will describe gravitational phenomena. Thus what Einstein had to do was to describe the connection between the description and measurements of phenomena going on in the box as made first by the man inside the box, second by the man outside the box. These two men will be observing the same thing but will, of course, give quite different descriptions. It is evident, too, that if we picture this falling box experiment performed on the sun, one observer being in the box and the other on the sun (naturally having the qualities of a salamander), they would give descriptions of things going on in the box which would be very different; but the differences between these would not agree with those noted in the first experiment performed near the earth. This is obvious, of course, because the gravitational field on the sun is so different, and the differences noted by the two men evidently depend upon this field. It is clear, then, that, if we knew exactly what these differences were, we would know all about the properties of the gravitational field. By means of mathematics we can discuss the forms which equations take in terms of one set of axes if they are given us in terms of another set, provided we know the relation between the two sets. In this case we do not know this relation; it is, in fact, what we wish to know in order to express our law of gravitation.

If I knew the exact law which described the manner in which the box fell at one point in a gravitational field, I would be able to make this mathematical transformation; but, of course, since the field is not the same everywhere I would have to use different transformations. Einstein, who conceived the idea of the falling box, stated his postulate in a manner equivalent to saying that at any one point in a gravitational field the box when falling would annul all gravity effects for an observer inside. This he called his "Principle of Equivalence." The study of this isolated phenomenon would not, however, give a general law of gravitation. So the problem is to find the first special relation and then generalize it.

So Einstein, with his mind fixed on the thought that this law must have the properties we have discussed, investigated different possibilities. He finally obtained a relation which satisfied all of his conditions, and thus he was able to state his law of gravitation. I fear it would be too great a strain upon you for me to follow all his line of argument; but I can assure you it is most convincing.

Let us make a résumé of the matter. We are discussing laws of nature, that is, the statement in mathematical form of the generalizations from our experiments and experiences. We cannot formulate these laws until we have definite modes of measurement of different physical quantities. These measurements must all refer to a definite system of coördinate axes; but, according to the principle of relativity the form of the law must be independent of the particular system used. It is necessary, therefore, to study those mathematical expressions which satisfy this condition; and, in order to select the proper one for a law of gravitation, we use as limiting conditions a Galilean system and the case of slow velocities, because for these conditions we know the experimental facts. We thus finally obtain a law for gravitation in a most general form. When we apply it to special cases, it is found to describe the motion of bodies falling near the earth and the motions of the moon, of comets and of the planets, because Newton's law is a special case of Einstein's. The latter, though, describes in a most satisfactory manner the motion of the planet Mercury, which Newton's law did not; and it also allowed Einstein to make a prediction in regard to the deflection of rays of light in an intense gravitational field such as exists near the sun, a prediction which apparently has been verified. I shall return to this last subject in a few minutes.

You will thus have seen, I hope, that Einstein has not proposed any theory of gravitation unless you wish to call a theory of this universal force his exposition of how subjective the whole concept is. I mean by this that the fact of our being always thinking of gravitation, of our always feeling and perceiving its effect, is due to the fact that we are living on the earth; if we were in our falling box, we would be absolutely unconscious of the whole phenomenon. In an absolute sense, therefore, we cannot say that it is real. This is a most important fact to recognize. As a theory of gravitation, it states that there is no reality to it.

Now in regard to the deflection of rays of light in a gravitation field, there are several things to be said. The first one should be that the facts of the rays being bent is evidence that the velocity of light is changed by a gravitational field, and this is in conflict with one of Einstein's first postulates. This need not trouble us, however, for to make even the faintest appreciable change in this velocity a great change in the field of gravitation is required, and such changes we personally never experience here on the earth. But you can easily see why one who is on the earth would observe a ray of light to be deflected from a straight path on coming into the field of gravitational force near the sun. Let us again recall the idea of the falling box. As has been explained, to an observer inside the box a projectile fired from a gun would appear to move in a straight line, so would a ray of light. Therefore, if it were possible to fire a projectile with a velocity as great as that of light, the observer can be imagined as watching the projectile and the ray moving side by side, as it were. Now to an observer at rest on the earth, the paths of all projectiles appear curved, so would a projectile near the sun, like a comet; therefore the path of the ray of light must appear curved, since it is parallel to the projectile. The only points to note are that, of course, the curvature of the path is extremely small, and a very intense field of gravitation is required to produce a curvature which we can actually detect, and also that, in order to predict how much this curvature is, we must know what it would be for a projectile moving so rapidly. Newton's law obviously should not be applied, as it could be for ordinary projectiles from guns; but Einstein could use his law, and he did. The calculation seems to agree well with observation. You may ask how do we observe a minute deflection of the ray of light; but the answer is really very simple. In fact, when I tell you, it will appear obvious. Consider the rays of light coming to us from a distant star; if we wish to receive them in a telescope, we point the instrument towards the star; if now the rays have been deflected, they will come to us from a different direction, and we shall have to turn the telescope until it points in the direction from which the rays are now coming. As you see, it is a very simple process.

I wish to call your attention to another very important deduction from Einstein's formulæ; but before doing this something should be said in regard to the general subject of theories, hypotheses and postulates. How are we to decide whether or not to accept them, to believe that we have attained truth? Any hypothesis, or postulate, is as we have seen, such a simple, such a general statement of belief that it is, as a rule, impossible to test it directly, we must resort to deductions. So what we do is to draw as many conclusions as possible from the postulates, conclusions which permit us to apply to their study our experimental methods. Then we test thoroughly these deductions. If they are verified, well and good; but if any one of them is not in agreement with experience we know that the postulates are not the proper ones. But, even if the deductions are apparently verified, we must always remember that our experimental methods and our best apparatus are very imperfect, and that our measurements are always accurate only to a certain percentage. Thus, if I am measuring the thickness of a wire or of a bolt, I am as a rule satisfied if I have an accuracy of one-thousandth of an inch; but, if I had two wires of the same thickness to within these limits, I would not say that they had identically the same thickness. A further consideration is the question as to whether or not there may not be other postulates which would lead to the same conclusions. Naturally this is an extremely difficult matter to settle, and we can never be convinced that we have disposed of all possibilities.

In the course of the development of a law for gravitation it is a consequence of Einstein's method that we learn something about the geometry of the space in which we live. As you know, Euclid and later mathematicians developed a science of geometry, in which, starting with certain axioms, postulates and definitions there is built up an elaborate structure of deductions. Thus circles, spheres, parallelograms, triangles, pyramids, cones, etc., are defined, and propositions are proved in regard to lengths, areas, angles and volumes. Every one knows certain of these theorems, *e.g.*, the one which states that the length of the circumference of a circle bears a constant ratio to its diameter designated by the symbol π and equal approximately to 3.14159, the one which states that the area of the surface of a sphere equals π times the square of the diameter, the one which states that the sum of the angles of a triangle equals two right angles, etc. I fear, though, that few people realize that all this work of Euclid and other geometers is a figment of the brain only. Its importance lies primarily in its being an illustration of a mathematical method. What I mean is this: suppose I were to do as most of you have done at school, take a string, fasten one end to a pencil or piece of crayon, then, holding the other end stationary on a blackboard or piece of paper, make the pencil or crayon describe a circle. Now, by my measuring rod let me *measure* the lengths of the diameter and of the circumference; will I find the ratio of these numbers to be π? Geometry has nothing to answer, it is not concerned with circles as we actually measure them. What geometry does is to say that if certain clearly stated axioms and postulates are granted certain conclusions are definite. Again suppose by mechanical means I make a sphere, and then measure the area of its surface, its volume and its diameter, will I find for my measurements the same ratios as those given by Euclid? I may or I may not. If I do not, then I know that the axioms or postulates made by Euclid are not a true picture of the space in which I am living and make my measurements. A kind of space in which Euclid's deductions would be verified by measurements would be called Euclidean space. Suppose we learn as a result of measurements of circles, spheres, etc., that our space is non-Euclidean, how can we discover what its properties are? This question may look at first rather hopeless, but I think I can explain by a few illustrations how we attempt to answer it.

We can picture a being who is himself flat like a visiting card, and who lives in a flat surface like the top of a large table, but unlimited, stretching out indefinitely. We can call this flat land; and the being living in and moving about in it is entirely unconscious of everything except what he meets in this surface, he cannot see anything above or below. He can build up a geometry of plane surfaces, circles, rectangles, triangles, etc. In particular;

he can start from any point and lay off lines of the same length in many directions from this point, like spokes of a wheel, and when he has drawn enough, he can make a circle by drawing a line connecting the ends of these lines, like the rim of the wheel. By laying off from the same centre longer radii he can describe other circles; he can measure the length of the circumferences and that of the diameters, and certainly if he is living in flat land, the greater he made his radius the longer would be the circumference of its circle. There is no apparent limit to the process. Further, if he wishes to describe the location of any point in his flat land, he has the means at hand; all he has to do is to number his concentric circles—in any way he wishes to, of course, having no duplicate numbers—and similarly number his radii. Then, if he says that a certain point is on circle twelve and radius fifteen, its location with reference to his starting point, the common centre, is definite. He simply has to give two numbers, so the flat-land is called a two-dimensional space. Again, suppose there is a sphere, a large one if you prefer, and suppose there is a being living in its surface, so he must have the shape of a little metal cap which fits the surface and slides over it. He can also start out from any point and lay off lines of equal length on the surface and can draw a circle connecting the ends of these lines. He can in this manner draw as many circles as he wishes; and again he can describe the location of any point on the surface with reference to his starting point by giving numbers in any arbitrary way to his lines drawn from this point and his circles. Again only two numbers are required, so he is living in a two-dimensional space. Bear in mind that this being knows only what his measurements tell him, he doesn't know anything about his land being a sphere, as we call it. Let us see what he could learn. First of all, his land has no limits; he never comes to an edge or a jumping-off point, any more than the man who lives in flat land. But he would observe that, after he had made his radius from his starting-point greater than a definite amount, the lengths of his circles became less and less; and, finally, if he made these radii all drawn from one point of just the right length, their ends would all coincide. In fact, he would have found the opposite pole. All this would be very interesting to him, but not surprising, because this is the only space he would know about.

The importance of these two pictures lies in the fact that it is evident that all that any being knows of the space in which he lives comes from the measurements he can make of geometrical figures which he can describe in his space. Now, of course, we know that we are living in a space of three dimensions, because, as I have explained before, if I wish to describe the location of any point in this hall, all I need are three numbers. But what kind of a space of three dimensions is it? Remember that both of the beings whom I have pictured, the one in flat-land and the one in the surface of a sphere, knew they were living in two-dimensional space; but their experiences were quite different. If the latter were asked by another being in the same surface: "What kind of a space is this in which we are living?" what would be the answer? Simply that, "The space is evidently two-dimensional and my measurements tell me certain things." There could be no picture given or any other description. Now, so it is with us, if you ask me what kind of a space is this in which we are living, all I can answer is that it is three-dimensional and that our measurements tell us certain facts. I cannot give you any picture. But what are the facts in regard to our measurements? In the first place we have learned by careful work that, so far as our measuring instruments permit us to know, the deductions of Euclid are verified. That is, when we measure the angles of a triangle and add them we obtain the equivalent of two right angles; the ratio of the length of a circumference of a circle to that of its diameter is π, etc. But we acknowledge that our measurements are not very exact; the real facts might be that Euclid's geometry is not verified, there being discrepancies so slight that we cannot prove their existence. The best we can say is that our space is certainly very nearly a Euclidean three-dimensional one.

The bearing of all this discussion upon our present consideration of Einstein's theory of gravitation is that his method enables us to say something with more or less certainty about the measurements of geometrical figures—circles, triangles, etc.—here on the earth. That is, Einstein's theory predicts the metrical properties of figures in a gravitational field. When we apply this theory, for instance, to the measurements of a circle, it appears that, according to it, the ratio of the measured length of the circumference to that of the diameter is not exactly π; but the difference between the two quantities is so small that in actual practice we could not detect it. Thus our statement made above in regard to the space in which we are living must, in accordance with Einstein's theory, be changed slightly, so as to be: we are living in a space of three dimensions, nearly but not perfectly Euclidean, and its properties can be expressed by certain mathematical relations. This is the best I can do, or the best any one can do, in giving a description of our space. The facts in regard to those relations are of interest to the mathematician or physicist only.

I must now conclude my lecture. My time and your patience are exhausted. I have indicated what I have thought were the essential features of Einstein's work, and have omitted many things which to a physicist are of supreme importance. I trust you have realized the novelty of Einstein's method, and I am sure you have been surprised to see what great consequences such apparently simple postulates have. To one who reads Einstein's papers with care, each page arouses admiration and inspires delight.

Hydrogen Ion Concentration of Pure Water.—H. T. BEANS and E. T. OAKES of Columbia University (*Journal of the American Chemical Society*, 1920, xlii, 2116–2131) have redetermined the hydrogen ion concentration of pure water and found it to be 1.23×10^{-8} or $10^{-7.91}$.

J. S. H.

Atomic Weight of Aluminum.—This constant of nature has been redetermined by THEODORE W. RICHARDS and HENRY KREPELKA of Harvard University (*Journal of the American Chemical Society*, 1920, xlii, 2221–2232). From the ratio of aluminum bromide to metallic silver, they find the atomic weight of aluminum to be 26.963.

J. S. H.

Mechanism of Bating.—JOHN H. WILSON (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 1087–1090) has made a study of bating, which is one stage in the manufacture of leather. For a bate, use was made of pancreatin or trypsin. Two distinct phenomena were produced by bating. The swollen limed skins were reduced to a condition of minimum swelling; and the elastin fibers, which are present in the outer layers of the skin, were digested.

J. S. H.

Long Electrical Transmission Lines in Europe. (*La Nature*, October 25, 1920.)—In this matter the United States of America holds the record with three lines almost 400 km. (250 miles) in length, that of the Au Sable Electric Co. in Michigan, 394 km. long, operating at 140,000 volts, the slightly shorter line of the Pacific Light and Power Co., Los Angeles, Calif., at 150,000 volts, and finally the system of the Southern Sierra Power Co., also in California, at 140,000 volts. In Europe Spain has the longest line. It runs from Molinar to Madrid and is 255 km. long. Next comes the Italian line from San Dalmazzo to Novi, 250 km. A second Spanish line from Molinar to Carthagena has a length of 213 km. All three of these are employing 70,000 volts, but two important lines supplying Barcelona, Spain, are at 88,000 and 110,000 volts, respectively.

In France there are two lines about 180 km. in length, one connecting Lyons to Bozel in the mountains of Savoy and employing the Thury direct-current system of transmission, while the other leads from Ventavon to Arles on the lower Rhone, the voltage being 50,000. There are several other French lines ranging from 150 to 160 km. in length. One of these from Ugine to Lyons transmits at 77,000 volts, thus far the highest A.C. voltage used in France for transmission purposes. There is, however, a line under construction from Olton Goesgen in Switzerland to Pouxeux, 156 km., which will operate at 100,000 volts, while the railroad company of the Midi is building a line to Bordeaux at 120,000 volts. G. F. S.

Addition Compounds of Sulphuric Acid and the Neutral Sulphates of the Alkali Metals.—By means of the freezing point method, JAMES KENDALL and MARY L. LANDON of Columbia University (*Journal of the American Chemical Society*, 1920, xlii, 2131–2142), have studied the formation of compounds in systems containing 100 per cent. sulphuric acid and an anhydrous neutral sulphate of an alkali metal: potassium, ammonium, sodium, and lithium. Each system was studied from its eutectic point up to a temperature of approximately 300° C. Both potassium sulphate and ammonium sulphate united with sulphuric acid to form two addition products; one molecule of sulphate was combined with one molecule of acid in one of these addition products, and with three molecules of acid in the other addition product. Sodium sulphate yielded three addition compounds, in which one molecule of that salt was combined with one, two, and nine molecules, respectively, of sulphuric acid. Lithium sulphate also yielded three addition products; however, one molecule of the salt was combined with one, two, and seven molecules, respectively, of sulphuric acid. Several of these addition compounds existed in two or more modifications.

J. S. H.

RECENT ATTAINMENTS IN WIRED RADIO.*[1]

BY

R. D. DUNCAN, JR.

Radio Engineer Signal Corps, U.S. Army.

I. INTRODUCTION.

Publications in the recent technical press have revealed that the problem of "Wired Radio" has aroused widespread interest within the last few years, both in this country and abroad, and in its many practical and theoretical phases has been the subject of extensive study and investigation.

The publication in 1911 by Major (now Major-General) George O. Squier, of a paper on "Multiplex Telephony and Telegraphy,"[2] marked an epoch in the scientific progress of the telephone and telegraph art. Though the problem of multiplex telephony and telegraphy had engaged the attention of a number of inventors prior to General Squier's work, the ideas underlying the schemes which hitherto had been proposed were based, almost without exception, upon the principles and practices of the old telephone art. The great advance made by General Squier, and that which made the use of high (radio) frequency carrier currents successful, was the combined utilization of tuned circuits, and a detector or rectifier at the receiving terminus. By this achievement the principles common to the radio art were made available to the older wire systems and a new method of transmission of intelligence was created.

The utility of wired radio was early realized in this country by certain of the telephone and telegraph companies, and its practical development in the realm of low frequency carrier currents has been carried to an advanced and commercial stage; long-distance telephone and telegraph lines employing the system are in daily operation between a number of large cities. That this country is not alone in the development of this new art is evidenced by the publications of Wagner,[3] Faszbender and Habann,[4] in Germany, and by Marumbo [5] in Japan. The two former papers contain interesting accounts of the development of wired radio apparatus in Germany during the war; the latter paper, though quite brief, is also of great interest, as it contains descriptions of methods and apparatus used where a high voltage power line was employed for transmission means.

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* Communicated by Major-General George Owen Squier, Chief Signal Officer, U. S. A., Member of the Institute, Associate Editor.

[1] "Wired Radio" refers to the use of high frequency currents guided by wires.

[2] *Trans. A. I. E. E.*, Vol. 30, 2nd Part, p. 1617, 1911.

II. PRELIMINARY EXPERIMENTS.

The practical development of wired radio was not pushed vigorously during the war by the Signal Corps, U. S. Army, as military requirements demanded apparatus of a more purely radio nature. A limited number of field telegraph sets operating on low frequencies were developed and manufactured. In an attempt to find use for a large quantity of radio telephone apparatus which had been purchased during the war, and which was then idle, experiments were commenced in the early part of 1919 with a view to investigating the possibilities of adapting this apparatus to wired radio communication. A brief account of these preliminary experiments has already been published in the JOURNAL of this Institute.[6]

In the experiments described, it was originally intended to employ frequencies of the order of 75,000 cycles per second for carrier purposes since in common with the prevailing opinion it was believed that the excessive values of attenuation which, it was thought, must occur at the high frequencies, would be prohibitive of transmission over anything but the very shortest distances. Accordingly, efforts were first directed towards altering the constants of the transmitting apparatus so that frequencies of this order of magnitude could be obtained. However, the radio telephone apparatus which was to be employed was originally designed for operation at high frequencies (short wavelengths) and on relatively small antenna capacities; from experiment it was found that if the original intention of using low frequencies was adhered to, a considerable change in the construction of the apparatus would be required. As a consequence it was decided to abandon the low frequency idea and to utilize, what had heretofore been considered the extremely high frequencies, as a carrier means.

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[3] Wagner: *Telegraphen u-Fernsprech Technik,* No. 3, p. 29, June, 1919.

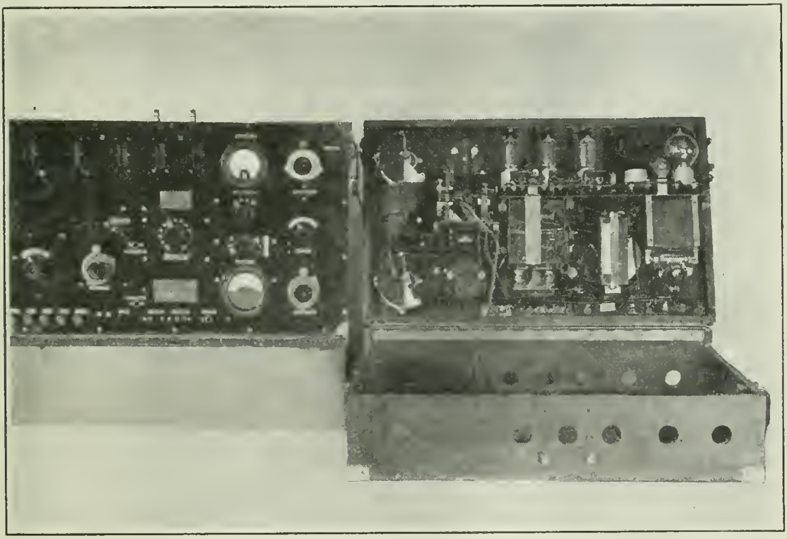
[4] Faszbender and Habann: *Jarhb. d. draht. Tel. und Tel.,* Band 14, p. 451, October, 1919.

[5] Marumbo: *Proc. I. R. E.,* Vol. 8, No. 3, p. 199, June, 1920.

[6] J. O Mauborgne, Vol. 188, p. 91, 1919.

One distinct advantage which was anticipated and which does result from the use of very high carrier frequencies is the elimination of speech distortion so common to long-distance wire telephony. In accordance with radio telephonic theory, three frequencies will be present in load circuit (antenna or telephone lines), if the modulating frequency contains no harmonics, *viz.*, respectively, the main carrier frequency, and the sum and the difference of the main carrier frequency and the modulating frequency. If harmonics are present in the modulating frequency, then in addition to the three main frequencies, there will be additional frequencies corresponding to the sums and differences of the main frequency and each of the harmonics. Assuming that the fundamental frequency of the voice is 800 cycles per second, and the limiting harmonic to be 3000 cycles per second, it is readily seen that at high carrier frequencies, the band of frequencies which is transmitted, is so small a percentage of the main carrier frequency that the attenuation to all frequencies

FIG. 1.



within the band is practically the same. The elimination of speech distortion due to this cause thus automatically results.

Views of the transmitting and receiving apparatus employed in the experiments are shown in Fig. 1; a diagram of connections of the circuit is given in Fig. 2.

The experiments were conducted on a wire belonging to the Postal Telegraph Company, running between Washington and Baltimore, a distance of 66 wire miles (106 Km.). The line was aerial throughout the distance of transmission and contained a single section of overhead cable approximately one-quarter of a mile in length; in the experiments the transmitting and receiving apparatus was connected between the line and the ground. The carrier frequency employed was 600,000 cycles per second. Throughout the entire tests the line was in ordinary duplex telegraph operation; no interference, either from the ordinary telegraph operation, or from the wired radio, was experienced by either system. The normal range of the apparatus when

Fig. 2.

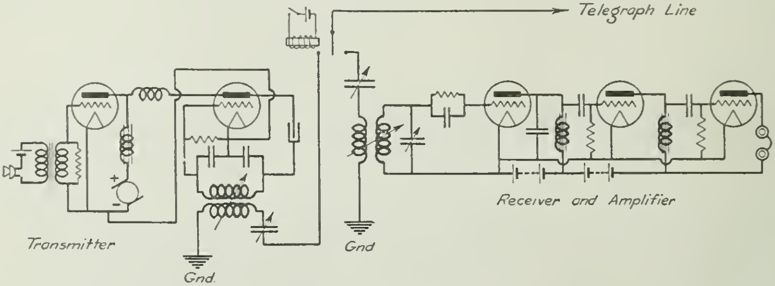
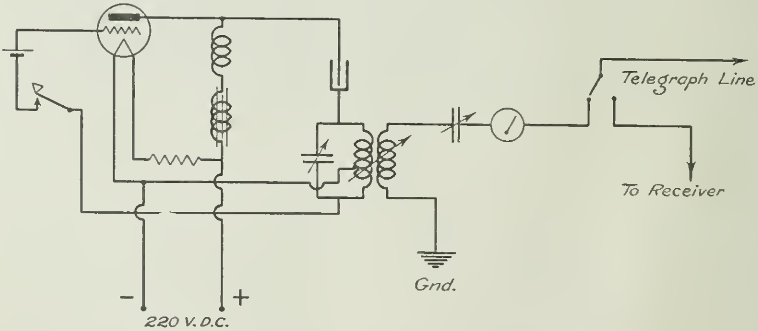


Fig. 3.



functioning as a "radio" telephone in communication with similar apparatus, is ten miles; it is seen that by the methods of wired radio, the range of communication was increased many times.

For telegraph purposes, only a vacuum tube transmitter was developed for operating directly from a 220-volt direct current lighting source. A diagram of connections of the apparatus is shown in Fig. 3.

The results of these preliminary experiments were of unusual interest, as it was demonstrated that transmission over relatively great distances could be accomplished with frequencies greatly in excess of the value which had heretofore been taken as the upper limit. From a practical standpoint, a number of questions arose requiring further investigation, of which probably the most important was that of determining the relative parts played by radiation and by true conduction, and of the distances over which satisfactory transmission might be expected to be obtained.

III. LATER EXPERIMENTS.

Further investigation along this line was made possible through the courtesy and coöperation of the New York Central Railroad Company. Through their General Superintendent of Telegraphs, Mr. E. C. Keenan, a pair of telephone lines running between New York City and Albany, N. Y., and two railway passenger coaches, stripped of their seats, were placed at the disposal of the Signal Corps. These cars were equipped with special and standard types of radio telephone and telegraph apparatus and auxiliary equipment, storage batteries, receiving and amplifying equipment, etc. An oscillograph was included as a part of the equipment of one car, for the purpose of studying telephonic modulation. During the actual field tests the two cars served as the abode of the members of the party. Views of the two coaches and an interior view of the coach which served as the fixed station, are shown in Figs. 4 and 5.

Experiments on the New York Central telephone lines were commenced the latter part of 1919. They had as their primary object a study of the possibilities of establishing communication over fairly long sections of line when employing extremely high carrier frequencies. The electrical properties of the telephone lines when serving as the load on the radio frequency generator were also to be studied, since from the information thus obtained,

FIG. 4.

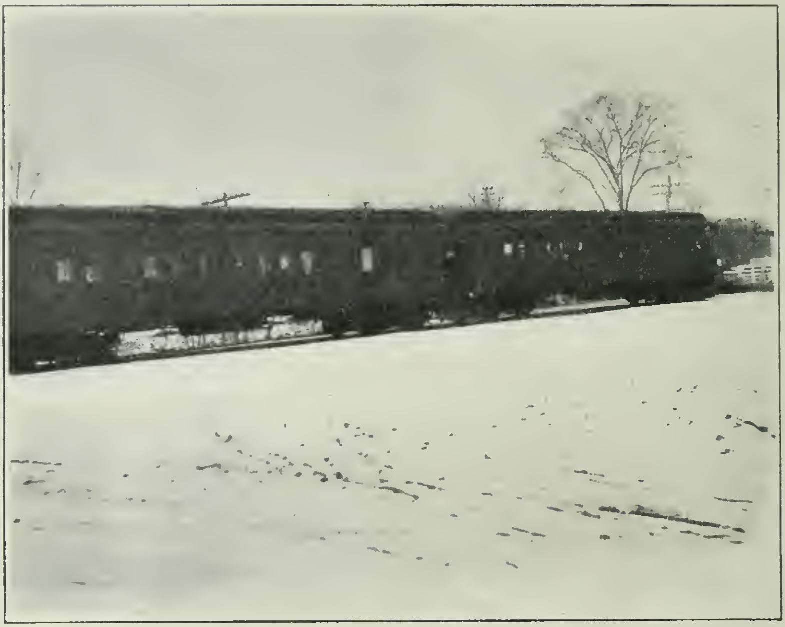
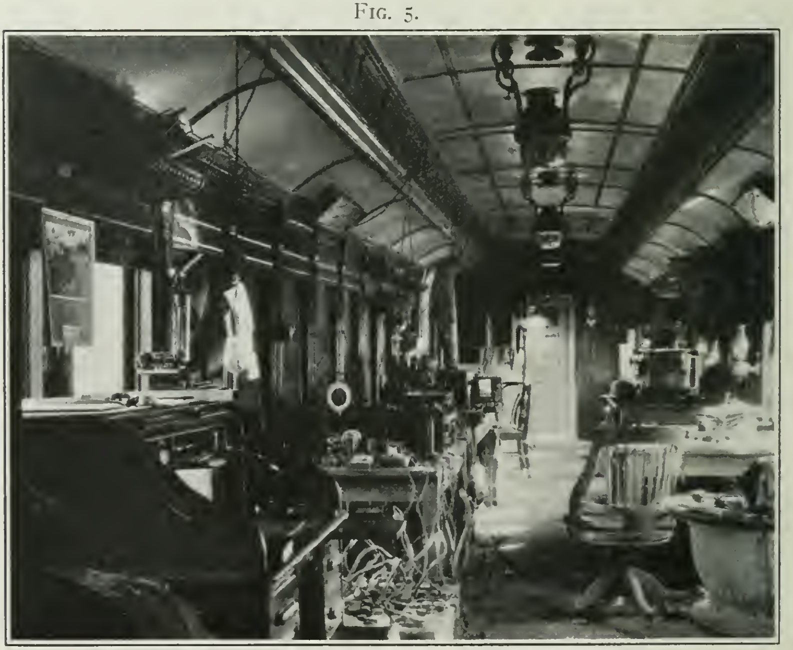


FIG. 5.

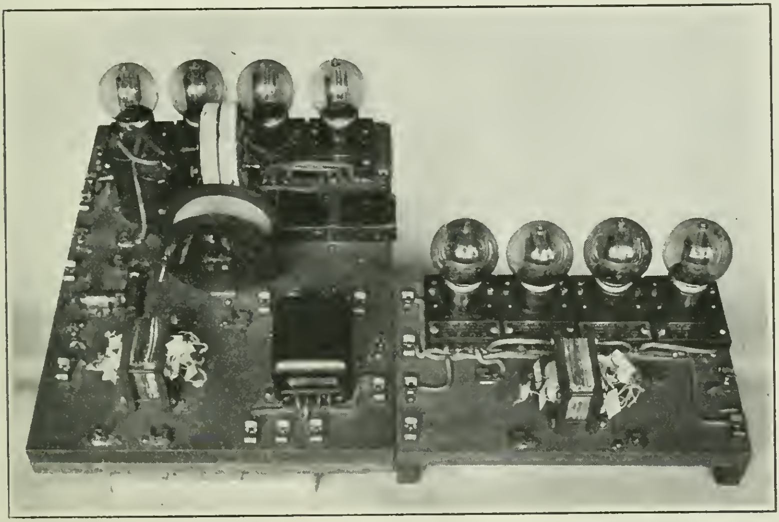


artificial line loads might be constructed upon which the development of future transmitting and receiving equipment could be based.

The transmitting apparatus employed throughout these tests consisted of that shown in Fig. 1, and in addition, special experimental apparatus shown in Fig. 6.

Two arrangements of the special transmitting apparatus were employed, one in which the telephone lines were coupled directly to the radio frequency generator circuit and one in which the modulated radio frequency power was first amplified by a bank of vacuum tubes connected in parallel, and then fed into the line load. The generating and modulating apparatus is shown at the left in Fig. 6; the power amplifier is shown to the right. The diagram of connections of the generating and modulating circuit when operating alone into the lines and when serving as the "master" set of the amplifier equipment, is shown in Fig. 7.

FIG. 6.

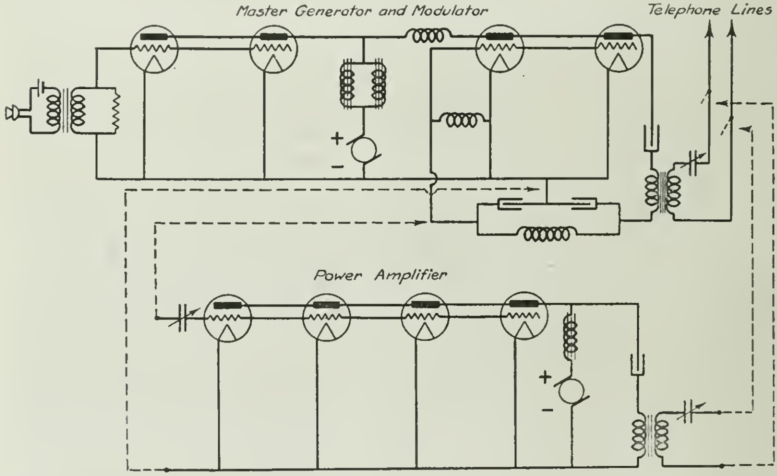


The type VT-2 vacuum tube was used for transmitting, two operating in parallel, in both the generating and modulating systems, and from one to four tubes in parallel in the power amplifier. Plate voltage for operating the transmitting tubes of the fixed station was furnished by a motor generator set driven from

110-volt power lines; in the mobile car plate voltage was furnished by dynamotors operating from storage batteries. The transmitting apparatus was arranged for telephonic operation and for both continuous wave and buzzer modulated telegraph operation.

The method of connecting or coupling the line load to the radio frequency generating unit is novel and possesses several features which are of value in duplex telephony. One annoying source of trouble in duplex telephony is interference produced on the receiving apparatus by the stray electric and magnetic fields of the transmitter. Experiment[7] has shown that the electric field may be confined to within known limits by shielding of the apparatus; the magnetic field, however, cannot be restricted by shielding and its disturbing effects may be minimized only by the proper design and displacement of the inductive and current carrying elements of the circuit. In the present circuit, energy is furnished to the lines through the means of a closed iron core transformer whose primary is connected, in series in the plate circuit, with the "frequency determining circuit." This transformer is designed to have a minimum magnetic leakage and its use permits of the further use of an inductance, in the frequency

FIG. 7.



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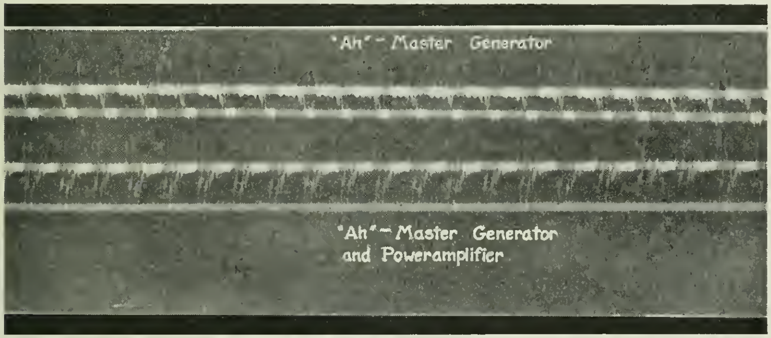
[7] Weinberger and Dreher: *Proc. I. R. E.*, Vol. 7, No. 6, p. 584, 1919.

determining circuit, of a compact form which has a very restricted magnetic coupling field. The requirement for a minimum magnetic disturbance due to this inductance is equivalent to the requirement of a minimum value of ampere turns of the inductance effective at a given point in space. A theoretical consideration of this type of circuit shows that for a given frequency, and constant number of turns in the frequency determining inductance, the disturbing magnetic field will be a minimum and the line current a maximum when the ratio of the capacities interposed respectively between plate, grid and common negative point of filament is made large. When this is the case, the effective resistance of the frequency determining circuit is small and the major portion of the high frequency power converted by the vacuum tube is expended in the load. Experiment confirms these conclusions. The increase in ratio of the plate to grid capacities in this type of circuit, aside from other practical considerations, is limited by its effect upon the telephonic modulation; it was found that if carried to an extreme, the degree of modulation was considerably reduced. The iron core transformer is seen in the foreground of the photograph of the generator unit in Fig. 6.

FIG. 8.



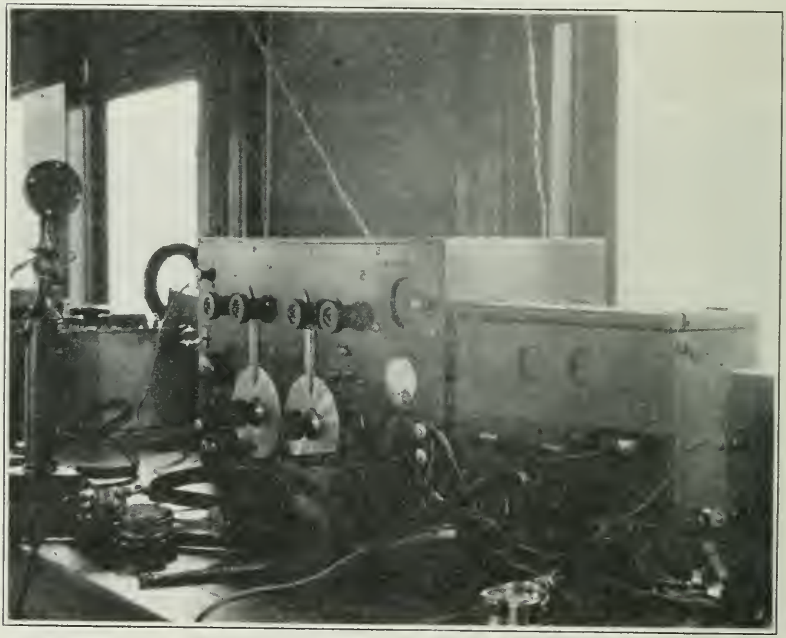
Oscillograms of the modulated high frequency output obtained from the generator, acting singly, and in conjunction with the power amplifier, are shown in Fig. 8.

The curves therein represent the envelop of the maximum amplitudes of the radio frequency currents, which are varied in accordance with speech frequencies; the straight lines about which the curves vary represent the unmodulated current. The oscillograms were obtained when the word "ah" was spoken into the microphone in a somewhat loud tone of voice.

The receiving equipment, shown in Fig. 9, consisted of a standard radio receiver and a two-stage audio frequency amplifier. The type *VT*-1 vacuum tube was used throughout.

One method of connecting the receiving apparatus to the telephone line is shown in Fig. 10. The apparatus employed in the later experiments was entirely experimental in character and was designed to obtain a high degree of flexibility in power output and in frequency. It was intended in no manner to represent a finished product.

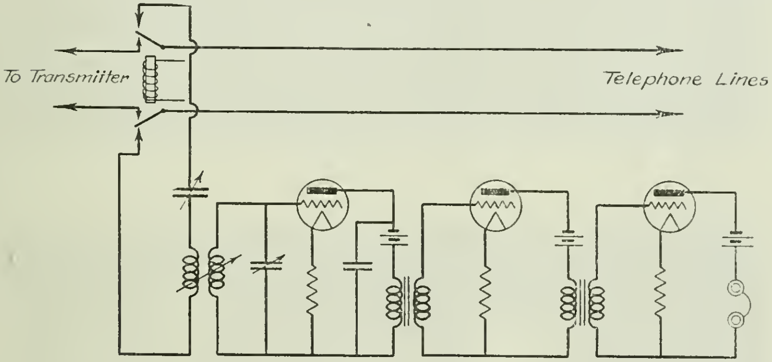
FIG. 9.



In adjustment of both the transmitting and receiving apparatus, the lines were tuned to resonance by means of the series line capacity. The tuning, while not as sharp as obtained with a radio antenna, revealed a distinct resonant point, and could be made broad or sharp at will, by altering the magnitude of the loading or coupling inductance.

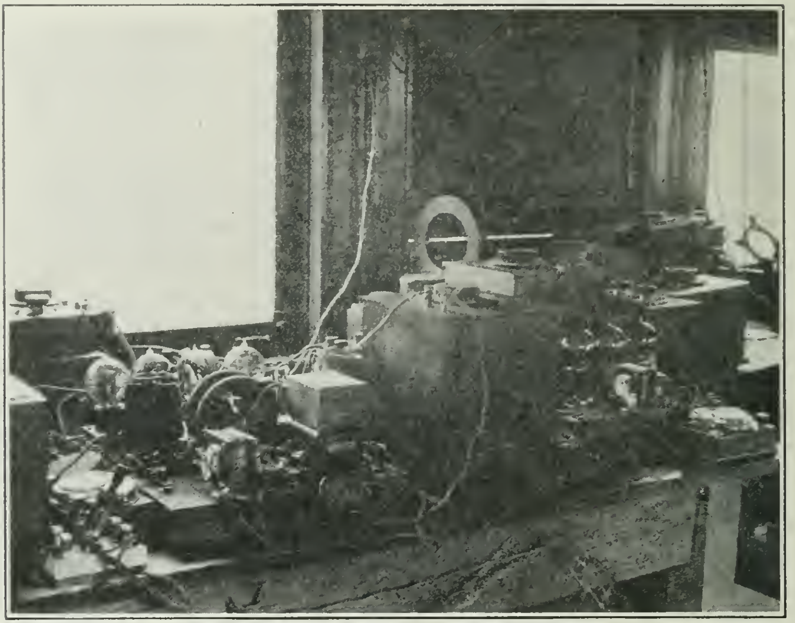
The transmission and reception tests were conducted on a pair of telephone lines running from New York City to Albany, N. Y., paralleling the Putnam and Harlem Divisions of the New York Central Lines, and the Boston and Albany Railroad for a short distance into Albany. The lines were aerial throughout the length effective in these tests and were transposed approximately every half mile; short lengths of overhead cable were included at three intermediate points where the lines entered stations for test purposes. These lines constituted the main telephonic channel of the New York Central Railroad between New York City and Albany and were in almost continuous operation. Besides being in ordinary telephonic operation the lines were composited, each wire of the pair operating a Morse circuit to ground. Throughout the experiments no interference with either system was produced by the other.

FIG. 10.

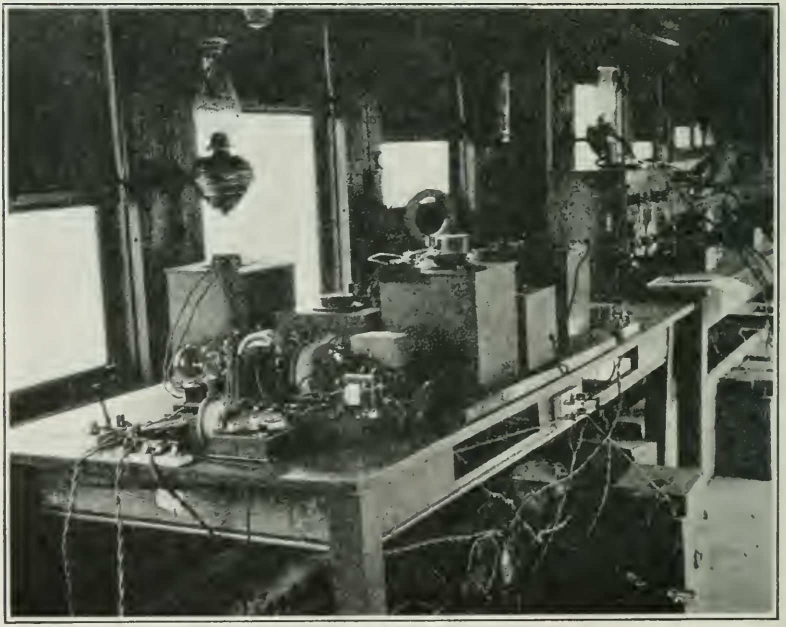


Telephonic and telegraphic communication was established over the pair of wires from Elmsford, N. Y., just north of New York City, and Albany, N. Y., a distance of 130 miles (209 Km.). A good quality of speech and both continuous wave and buzzer modulated telegraph signals were obtained. The carrier frequency varied from 600,000 to 300,000 cycles per second (wavelength 500 to 1000 metres). The high frequency power output varied from less than one-half watt to twenty watts, depending upon the apparatus used. It is to be observed in this respect that when dealing with radio telephone circuits, in contradistinction to those used in radio telegraphy, an indication of maximum cur-

Fig. 11.



Apparatus in fixed station.



Apparatus in mobile station.

rent into the load is not always indicative of most efficient operation. What is sought and that which is the most effective at the distant receiving station, is the faithful and complete telephonic modulation of the power output that is available. A large power output incompletely or imperfectly modulated is no more effective than a smaller one more completely modulated and modulated with less distortion. Views of the transmitting and receiving equipment of both the fixed and mobile stations are shown in Fig. 11.

In the Washington-Baltimore experiments, as well as in the later ones, evidence of the existence of standing waves on the telephone lines was obtained; this was quite noticeable in the moving-train experiments later described. Standing waves, as is well-known, are produced by reflection from either the far end of the line, or from intermediate points where there occurs a sudden transition in the electrical properties such as produced by the introduction of short lengths of cable, changes in the size of conductor. In the latter case, unless the reflection is complete, a portion only of the outgoing wave will be turned back, and a portion will proceed unreflected; as a result there will occur partial reflection and partial unreflected transmission. The location of the receiving apparatus with respect to the transmitter, when standing waves are present, is therefore determined largely by the wave-length or frequency of the carrier wave, since for efficient reception, it is necessary to avoid both voltage and current nodes. It was found that altering the frequency at the generator terminal apparently did not produce an effect in moving the nodes and loops along the lines equivalent to that of moving the receiving apparatus.

In the preliminary experiments previously mentioned, and in the earlier New York Central tests, one overhead wire with a ground return was employed. A comparison of this arrangement with an all-metallic circuit showed that the latter was the much superior of the two, both as to volume of speech received and elimination of external disturbances such as that produced by nearby radio stations. The reason for this improvement is attributable to the pronounced energy radiating and absorbing properties possessed by the one elevated wire with ground return. Both the direct current and " skin effect " resistance of a metallic loop should be equal to approximately twice that of one wire and ground. Theory indicates, however, that the resistance introduced by radiation is proportional, among other factors, directly to the effective distance between the conductors, which in the case of an elevated wire with ground return, is equivalent to the distance between the wire and its "electrical image" in the earth or to twice its physical height above the ground. This distance, of course, is many times greater than the spacing between the two metallic conductors and hence at frequencies where the radiation plays an important part, the effective resistance of the latter system should be much less than the wire-ground system. This conclusion is borne out by the tests referred to and by actual resistance measurements which are described later on.

The question of cross-talk was investigated, as it was believed that at the high frequencies inter-line disturbances might be prohibitive of utilizing the same carrier frequency on more than one line or pair of lines on the same pole. In the Washington-Baltimore tests, it was found that it was possible to receive signals with the lead wire to the receiving apparatus disconnected from the line in question and held in the immediate vicinity of the same or wrapped around, but not making contact therewith. Signals of reduced intensity were also received with the lead wire connected to other immediately adjacent lines on the same cross-arm. Complete elimination of cross-talk to other lines, however, was obtained when the first few miles of conductor adjacent to the transmitting apparatus ran through underground cable. When employing an entire metallic circuit, at the very highest frequencies used, there was a complete absence of cross-talk to the other conductor pairs on the same pole line.

The problem of multiplexing the lines was also studied, but limitations in time available for field operations did not permit of utilizing the degree of thoroughness which the successful solution of this intricate problem demands.

As a prerequisite to the solution of the main problem of multiplex there are the solutions of the two allied problems of multiple transmitter operation and duplex telephony; by duplex telephony is meant simultaneous transmission and reception, accomplished without the assistance of switching devices. The difficulties encountered in multiple transmitter operation are not serious and are easily overcome; those encountered in duplex telephony, however, if the band of frequencies available is restricted, are most serious, and become almost insurmountable if the receiver sensitivity is at all heightened by the use of radio frequency amplifiers. Utilizing artificial line loads, the design and construction of which is described elsewhere in this paper, the problem has been successfully solved in the laboratory at the present writing, only by paying the most strict attention to details of apparatus, design, construction, and shielding.

IV. MOVING-TRAIN EXPERIMENTS.

A very interesting application of wired radio is that of establishing communication with a train while in motion. The utility of such a system for insuring greater safety of travel, transmission of business information, etc., is readily realized. In 1914 and 1915 experiments were carried on by the Delaware, Lackawanna and Western Railroad with a view to establishing such a service by *radio*. According to reports published at that time[8] transmitting powers in the neighborhood of one kilowatt and antennas averaging 150 feet in height and between 200 and 400 feet in length were employed. With this arrangement, telephonic communication of a more or less satisfactory character was obtained between a moving train and a fixed station for distances up to 50 miles (80 Km.). It was reported that the directional properties of the transmitting and receiving antennas utilized in these tests were very noticeable; when the train was in movement over a section of track containing numerous curves, the received signals fluctuated greatly in intensity. As adapted for this purpose, wired radio utilizes the telephone conductors paralleling the railroad tracks as a properly directed path for the carrier frequency currents. The transmitting and receiving apparatus at the fixed station was connected between one aerial wire and the ground; in the moving station the apparatus was connected to a closed loop, properly orientated with respect to the telegraph wires. The transfer of energy from the elevated wires to the loop, or *vice versa*, is effected by the inductive action of the electromagnetic field. Employing this system and with high frequency powers in the neighborhood of 2 watts, an excellent quality and quantity of telephonic speech and telegraphic signals were obtained between the two railroad coaches, one stationary and the other in motion, over distances ranging up to ninety miles (145 Km.). During the moving-train tests, the presence of standing waves on the lines was again verified; the signals received in the moving station varied periodically in intensity as the car was under way.

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[8] *Electrical World*, Vol. 66, p. 570, 1915.

V. HIGH FREQUENCY LOAD CHARACTERISTICS OF THE TELEPHONE LINES.

Theory.

A knowledge of the electrical load properties of the two elevated conductors or of one conductor with ground return, when operating at the extremely high frequencies, is prerequisite to the design and development of both transmitting and receiving apparatus. *A priori,* it is known that the load resistance and reactance of the lines, *i.e.*, the effective resistance and reactance into which the radio frequency generator works, and in effect the internal resistance and reactance of the generator which furnishes power for operation of the receiving apparatus, are functions of the frequency. The exact manner of their variation with the frequency is implicitly contained in the standard theory of transmission lines, but so far as the author is aware, only a limited amount of experimental data has been published which tends to confirm the theory at the low range of high frequencies and practically none when extremely high frequencies are dealt with. With such information artificial lines may be constructed which will permit of a thorough study of the high frequency properties of transmission lines and upon which the development of transmitting and receiving apparatus may be based. The problem corresponds to the problem of measurement of the constants of a radio antenna.

In accordance with the theory,[9] a distributed circuit such as an elevated telephone line, of length l, possesses per unit length, inductance L, capacity C, resistance R and leakage conductance G. The ratio of the voltage applied at the generator terminals of the distributed circuit, to the current input at the same point, for the conditions of the far or receiving end open, and short-circuited upon itself, after the transient state has disappeared, is given by the two following vector expressions. For the receiving end open-circuited:

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[9] Malcolm: "Theory of Submarine Telegraph and Telephone Cable," Chap. vi. Pernot: "Electrical Phenomena in Parallel Conductors," Vol. I, Chap. viii.

$$(1) \ldots\ldots\ldots\ldots Z' = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \cdot \coth \cdot l \cdot \sqrt{(R+j\omega L)(G+j\omega C)}$$

For the receiving end short-circuited upon itself:

$$(2) \ldots\ldots\ldots\ldots Z'' = \sqrt{\frac{R+j\omega L}{G+j\omega C}} \cdot \tanh \cdot l \cdot \sqrt{(R+j\omega L)(G+j\omega C)}$$

wherein $j = \sqrt{-1}$, and coth and tanh represent the hyperbolic cotangent and tangent of the complex angle indicated.

In transmission engineering Z is generally termed the "final sending-end impedance." If the line losses are assumed to be zero, *i.e.*, $R = G = 0$, the impedance Z, for the two conditions degenerates into a reactance, and equations (1) and (2) may be written in the form:

$$(3) \ldots\ldots\ldots X' = -\sqrt{\frac{L}{C}} \cdot \cot \cdot l \cdot \sqrt{\omega^2 L C}$$

$$(4) \ldots\ldots\ldots X'' = \sqrt{\frac{L}{C}} \cdot \tan \cdot l \cdot \sqrt{\omega^2 L C}$$

Under the conditions of zero line losses, the line reactance effective at the transmitting apparatus is seen to be a function of the frequency ($\omega = 2.\pi.f$) since both the circular cotangent and tangent are periodic functions of ω, varying from minus infinity to plus infinity. From equations (3) and (4), it is evident that the reactance becomes zero respectively when:

$$(5) \ldots\ldots\ldots\ldots \omega = \frac{1}{\frac{2}{\pi N}\sqrt{lL \cdot lC}}$$

and

$$(6) \ldots\ldots\ldots\ldots \omega = \frac{1}{\frac{2}{\pi N'}\sqrt{lL \cdot lC}}$$

where $N = 1, 3, 5, 7 \ldots$; and $N' = 0, 2, 4, 6 \ldots$ The fundamental frequency is obtained when $N = N' = 1$, and is given by

$$(7) \ldots\ldots\ldots\ldots f = \frac{1}{4\sqrt{lL \cdot lC}}$$

The case of *quarter-wave* oscillating systems of relatively low losses, such as is closely approximated by the radio antenna, falls under equation (3) and has been discussed extensively by Stone,[10] Cohen,[11] Miller,[12] and Wagner.[13]

It is, of course, impossible to obtain a line entirely free from losses, particularly at high frequencies, where, as theory indicates, the effective resistance due to skin effect and radiation may become very large. In this case equations (3) and (4) no longer represent the true condition of affairs and equations (1) and (2) apply. Both of these latter are vector equations involving the hyperbolic tangent and cotangent of the complex angle

$$[l \cdot \sqrt{(R+j\omega L)(G+j\omega C)}]$$

These two functions go from maximum to minimum values as the complex angle passes through multiplex of $\frac{\pi}{2}$, and hence it is to be expected that the impedance will vary in a somewhat corresponding manner. Equations (1) and (2) may be split up into real and complex components, respectively, representing the effective load resistance and reactance of the lines; the resulting expressions are, however, rather complicated and without substitution of actual numerical values are difficult of interpretation.

Measurements of the sending end reactance and resistance as functions of the frequency, of an artificial transmission line, whose receiving terminals were open, over a range of frequencies up to and including the third harmonic, have been described by Morecroft,[14] who obtained a periodic variation in the reactance from positive to negative values, and a pulsation in the resistance values.

In a distributed system in which the physical length is very great in comparison to a wave-length, it is evident that the line load may function either as a positive or negative reactance depending upon the frequency of the impressed emf; the resistance will also vary between certain maximum and minimum values.

The theory as is generally given requires modification when considered from the standpoint of high frequencies, since it is implicitly assumed that the four line *constants, viz.*, the unit resistance, inductance, capacity and leakage conductance are constant and independent of the frequency. This assumption is quite valid when dealing with very low frequencies, but does not hold for all of the four line constants at high frequencies. Two agencies act to make this the case, *viz.*, the progressive unequal distribution of current over the conductor cross-section as the frequency is increased, and the finite velocity of propagation of the electromagnetic field; this velocity is taken to be equal to that of light, *viz.*, 3×10^{10} centimetres per second. The first of these phenomena, commonly known as "skin effect," causes the inductance of the conductor to decrease and its resistance to increase, as the frequency increases. Expressions have been derived and tables prepared[15] which permit the rapid calculation of the change in the inductance and resistance of straight wires for frequencies from 100 to 3,000,000 cycles per second. It is of interest to note in this respect that the inductance change with the frequency is relatively slight while the change in resistance may be very great. As an illustration of the changes predicted by the theory for the case of a pair of No. 9, A. W. G. hard-drawn copper wires, spaced fifteen inches, the inductance computed for the frequencies of 25,000 and 1,000,000 cycles per second were respectively 3.68×10^{-3} and 3.60×10^{-3} henrys per loop mile, or a change of 2 per cent.; the corresponding values of resistance at the two frequencies are very closely equal to 16 ohms and 90 ohms or a change of over 500 per cent. So far as is known the unit capacity of the lines is not affected by the change in current distribution with the frequency.

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[10] Stone: *Trans. Int. Elec. Congress, St. Louis,* Vol. 3, p. 555, 1904.

[11] Cohen: *Bul. Bu. of Standards,* Vol. 6, No. 2, p. 247, 1909.

[12] Miller: *Proc. I. R. E.*, Vol. 7, No. 3, p. 300, 1919.

[13] Wagner: *Arch. d. Elektrotecnik.*

[14] Morecroft: *Proc. I. R. E.*, Vol. 5, No. 6, p. 389, 1917.

In low frequency alternating current work where the physical dimensions of the apparatus or circuits are small, in comparison to a quarter wave-length of the fields, the velocity of propagation is properly assumed to be infinitely great. At radio frequencies this assumption may or may not be permissible, depending upon the frequency and physical displacement of circuits. The effect which a finite velocity of propagation has upon the circuit constants has been investigated mathematically by Steinmetz,[16] who has arrived at the conclusion that of the four line constants the resistance was the only one to be affected when the frequency was increased to large values but did not exceed approximately 1,000,000 cycles per second. Expressions for inductance and capacity of a pair of lines or of one elevated line with ground return, as computed on a basis of finite propagation (when corrected for skin effect if necessary), were proven to be valid at high frequencies as long as the limit specified was not exceeded. The resistance was found to increase at a rate proportional, among other factors, directly to the spacing between the conductors and to the square of the frequency. For the case of a pair of wires, *i.e.,* a complete metallic circuit, this distance is comparatively small; however, in the case of a single conductor with ground return, the effective spacing between conductors is equal to the distance between the elevated conductor and its electrical image in the earth, or to twice its physical height above the ground. The radiating properties of both distributed systems should become the more pronounced as the frequency becomes higher; those of the wire-ground system should, for a given frequency, be more pronounced than of the two-wire system.

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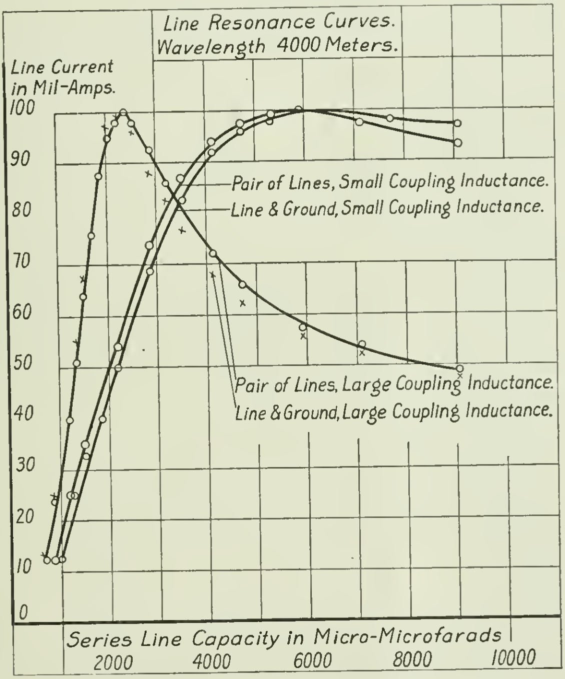
[15] *Scientific Paper No. 169, Bureau of Standards,* pp. 172 and 226, 1916.

[16] Steinmetz: *Proc. A. I. E. E.*, March, 1919.

In the derivation of equations (1) to (4), the additional assumption was made that the lines in question were free in space and consequently were unaffected by the presence of other lines or by the nearby presence of the ground. These conditions, however, are rarely ever completely realized in practice; the lines used in these particular tests, throughout their entire length, were included on the same pole with other lines, the total number of lines in some locations running as high as one hundred or more.

As a brief summary it may be stated that, if the accepted transmission line theory does not suffer serious modification when corrected for change of inductance and resistance, and for a possible change of the leakage conductance, about which little is known, for increasing frequency, it is to be expected that the impedance of the lines, measured as functions of the frequency from the generator end, will undergo a periodic variation between maximum and minimum values, as the frequency increases. From a consideration of the theory as outlined briefly above, and from reported observations of measurements on artificial lines, it is to be further expected that the two components of the impedance, *viz.,* the effective reactance and resistance of the load, will undergo a similar periodic variation, the former passing from positive to negative values, the latter pulsating between the maximum and minimum positive values. In the line measurements described in the following, because of the extremely low potentials applied to the line, it was impossible to accurately measure the impedance as would be computed from observed ratios of the applied voltage to the current input. Instead, the reactance and resistance of the line load were measured separately by the methods later described.

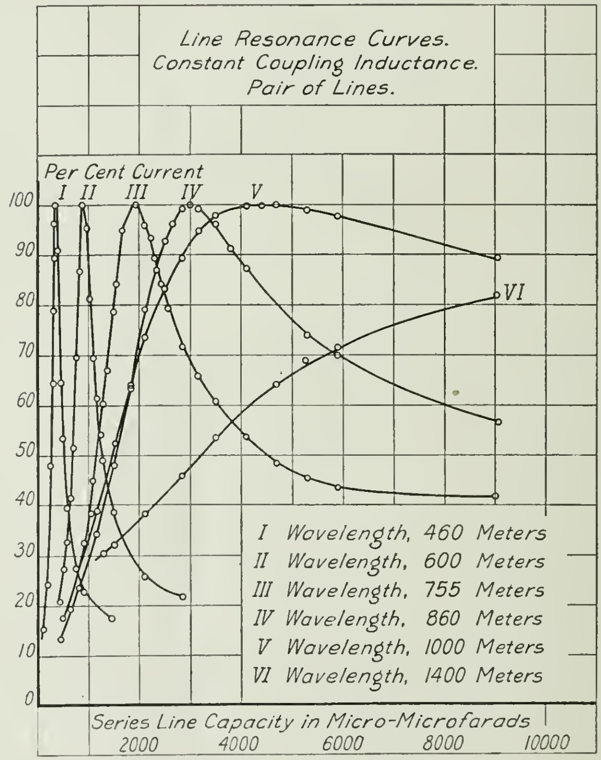
FIG. 12.



VI. LINE LOAD MEASUREMENTS.

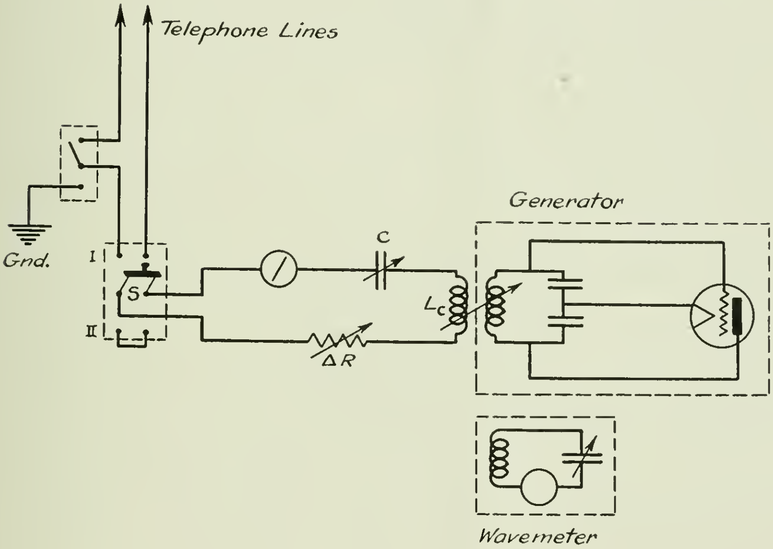
In the adjustment of the transmitting apparatus during the transmission and reception tests, maximum line current was obtained by resonating the load, including both the lines and local circuit, to the operating frequency; this was accomplished by variation of the series line capacity. The tuning features of the line load are illustrated by the curves shown in Figs. 12 and 13. In the former are plotted values of line current against values of series line capacity for both a pair of lines and for one line and ground, for two different values of coupling inductance, but with a constant frequency of 75,000 cycles per second (wave-length 4000 metres); as is to be expected, the tuning is sharper with a large coupling inductance than with a smaller one, the effect in the former case being to "stiffen" the line. The same result is to be accomplished by maintaining a constant value of coupling inductance and varying the wave-length; as shown in Fig. 12, the line tuning becomes broader as the wave-length is increased. The ordinates of the curves in this figure were computed on the basis of assigning a value of 100 per cent. to the observed maximum values of each curve and computing the values of the other points as a percentage of 100.

FIG. 13.



The reactance and resistance measurements were also based upon the phenomena of resonance. Referring to Fig. 14, wherein is shown the circuit employed during measurement, it will be observed that the line load in series with a variable capacity C and resistance ΔR, is inductively coupled to the radio frequency current generator through the inductance L_c. With the resistance ΔR, set to zero, and with the switch S in position I, the capacity C is varied until the entire load, including both the lines and local circuit, is in resonance, as indicated by a maximum reading of the line ammeter. In this condition the reactance of the capacity C exactly neutralizes the combined reactance of the inductance L_c and of the lines; readings of the series capacity and frequency are noted. Switch S is then thrown into position II, which in effect short-circuits the lines so far as the generator is concerned; maintaining the frequency the same as before, the series capacity is again varied until resonance is obtained and a second value noted. The algebraic difference in values of the reactance of the series capacity for the two settings gives the sign and magnitude of line reactance. The line resistance was measured by the "half-

FIG. 14.



deflection" method. The theory of the reactance measurements is briefly as follows:

For a given frequency, $f = \frac{V}{\lambda} = \frac{\omega}{2\pi}$, where V is the velocity of light, let

$X_L \equiv$ reactance of the line load, (positive or negative),

$C_1 \equiv$ value of capacity C, which gives resonance when switch S is in position I

$X_1 \equiv \frac{1}{\omega C_1}$ resonant reactance of C_1 viz., of lines, plus inductance, L_c, plus leads.

$C_{11} \equiv$ value of capacity C which gives resonance when switch S is in position II. i.e.. lines short circuited.

$X_{11} \equiv \frac{1}{\omega C_{11}}$ resonant reaction of C_{11} viz., of inductance L_c and leads.

$X_c \equiv \omega L_c$, reactance of inductance L_c, plus leads.

$\triangle R_1 \equiv$ resistance of line load, plus inductance, plus leads.

$\triangle R_2 \equiv$ resistance of inductance L_c plus leads.

$R_L \equiv$ resistance of lines.

Then at resonance, with $\triangle R_1 = O$, and switch S in position I,

(5)................................ $X_1 = X_L + X_c$

With S in position II, also at resonance,

(6)................................ $X_{11} = X_c$.

Therefore subtracting (6) from (5),

$$X_L = X_1 - X_{11}$$

(7)................................ $= \frac{1}{\omega C_1} - \frac{1}{\omega C_{11}}$

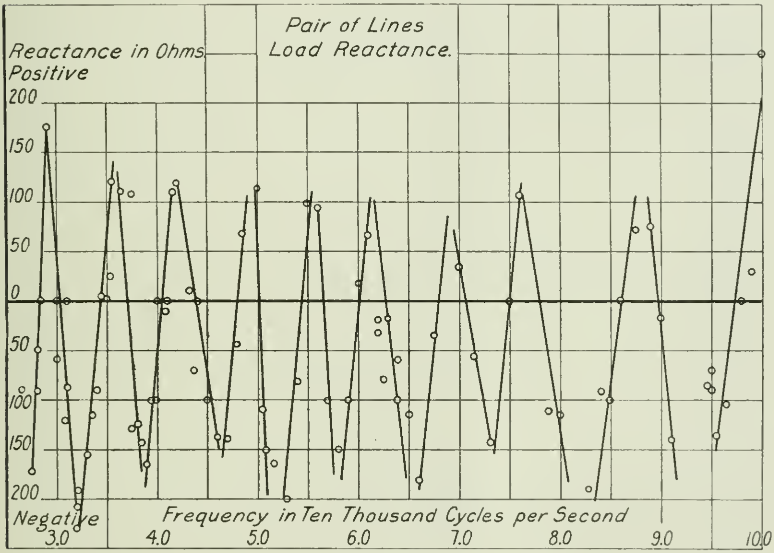
If $X_1 > X_{11}$, X_L will be positive, if $X_1 < X_{11}$, X_L will be negative. Readings of λ, C_1 and C_{11} therefore permit of the calculation of the effective line reactance. The resistance was measured by the *half-deflection method* which at the two resonant points, yields,

$$R_L = \triangle R_1 - \triangle R_{11}$$

The results of the measurements are shown graphically in Figs. 15, 16, 17, 18, 19 and 20. In Figs. 15 and 16, respectively, are plotted values of the sending end reactance and resistance of the pair of lines employed, as functions of the frequency, for frequencies between 25,000 and 100,000 cycles per second; in Figs. 17 and 18, respectively, are plotted values of the same two functions in terms of the wave-length, for the range of wave-lengths 3000 to 300 metres (frequency 100,000 to 1,000,000 cycles per second). In Figs. 19 and 20, the variation of the sending end reactance and resistance of one line with ground return, as a function of the wave-length is plotted for wave-lengths between 3000 and 300 metres.

In making the reactance and resistance measurements, difficulty was experienced in obtaining the necessary accuracy required at the low frequencies (long wave-lengths). At times a change in frequency, which could hardly be detected by the wave-metre, was sufficient to cause the line reactance to vary from relatively high positive to equally high negative values. The physical conditions of the lines also seemed to vary at times during the measurement, causing the resonant point to rapidly shift back and forth with a consequent fluctuation in the ammeter reading. The points plotted in Figs. 15 and 16 were obtained with all possible accuracy and the curves drawn there through qualitatively confirm the prediction of the theory. The errors of observation in the wave-length values, from which the frequencies

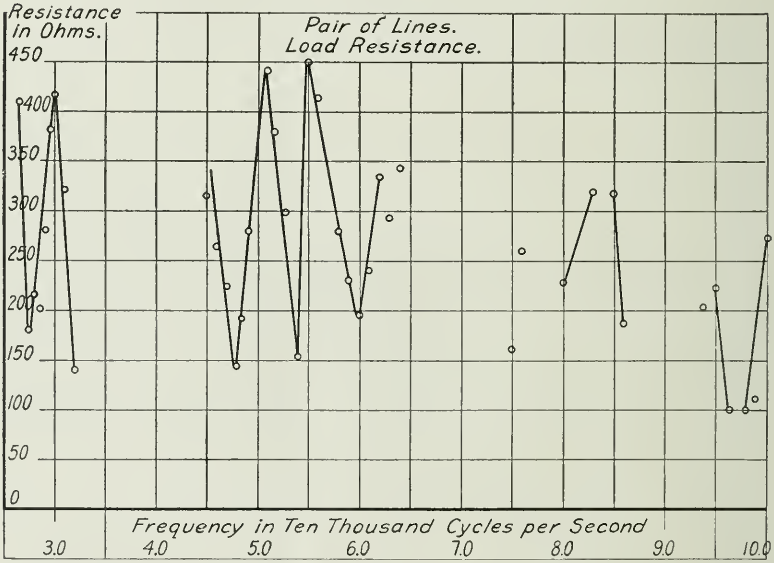
FIG. 15.



were computed, are magnified by the abscissa scale chosen for these figures which permits of plotting to a greater accuracy than could be obtained in making the readings; this particular choice of scale was made in order to secure greater ease in plotting.

In accordance with theory as shown by equations (3) and (4), if the line resistance and leakage conductance are negligibly small, for certain frequencies, the reactance should attain infinitely large values. A glance at Fig. 15 shows this not to be the case for the particular lines measured; so far as could be determined the reactance not only did not reach excessively high values, but passed through a second set of zero values. The actual measured value of the sending end resistance further shows that the resistance factor, which represents the combined effect of the linear resistance and leakage conductance, is not a negligible quantity. It will be observed on comparison of Figs. 15 and 16, that at zero reactance points where the slope of the reactance curve is positive, where data was obtained, the resistance reaches its minimum value; maximum resistance values are obtained also at zero reactance points, but where the slope of the reactance curves is negative; the average value about which the resistance varies is

Fig. 16.



approximately 250 ohms. Points of zero reactance occur at intervals of approximately 6500 cycles from 28,000 to 75,000 cycles per second, beyond which up to 100,000 cycles per second, they occur at intervals of nearly 11,000 cycles per second. The curves in general are similar to those obtained by Morecraft[17] for an artificial line at low frequencies. The reactance and resistance measurements were made with the lines in ordinary telephone and

FIG. 17.

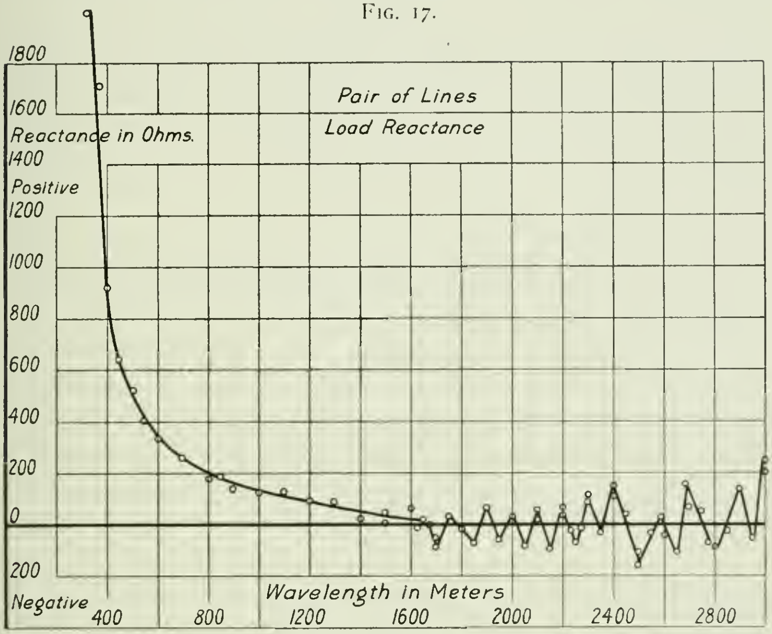
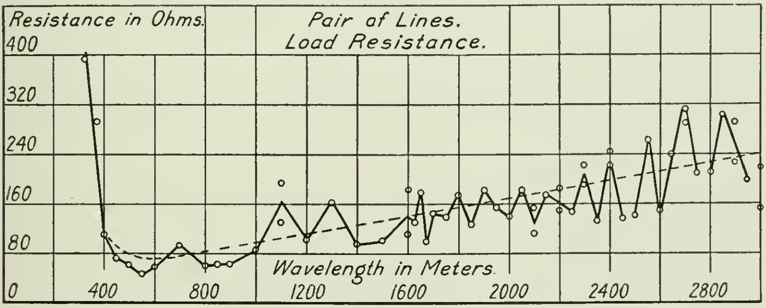


FIG. 18.



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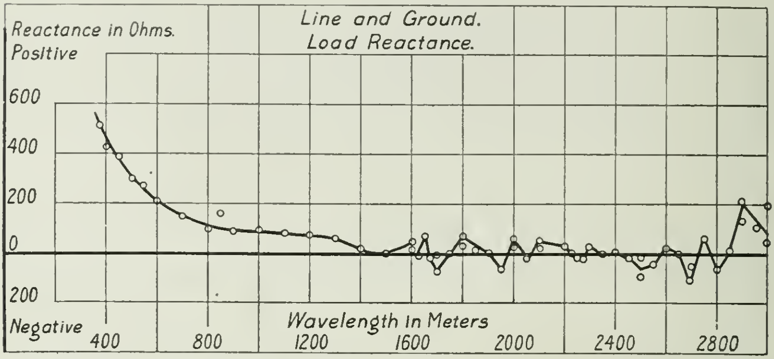
[17] Morecroft: See previous reference.

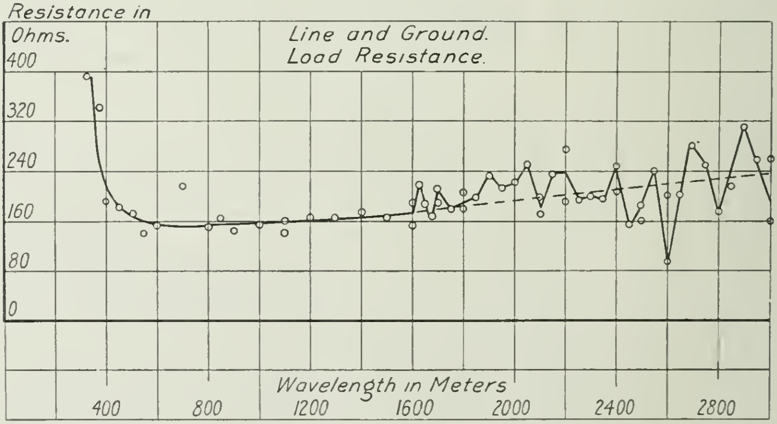
telegraph operation as these are the conditions under which wired radio apparatus will be forced to work. The exact qualitative and quantitative confirmation of the theory is hardly to be expected since the line conditions under which the measurements were made differ widely from those assumed by the theory.

FIG. 19.



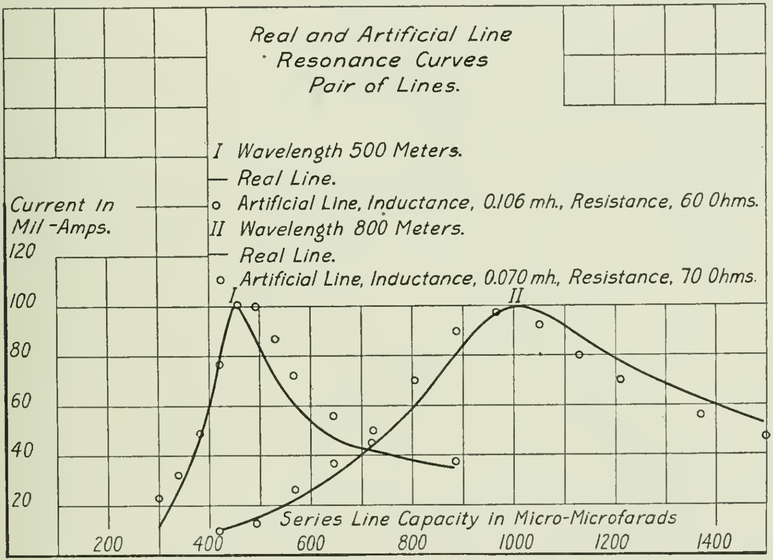
In Figs. 17 and 18, for accuracy and convenience, the reactance and resistance of the pair of lines, are plotted in terms of the wave-length, for wave-lengths between 3000 and 300 metres (frequency 100,000 to 1,000,000 cycles per second). Figs. 19 and 20 show the same quantities for one line and ground plotted in the same manner. From Figs. 17 and 19 it is seen that the periodic variation in reactance persists, as at the lower frequen-

FIG. 20.



cies, but not in so definite manner, until a wave-length of 1600 metres (187,500 cycles per second) is reached, below which it remains positive in sign, but increases in a quite uniform manner; the pulsation in resistance values for both line and line, and line and ground, also continues as shown in Figs. 18 and 20, the average value in both cases decreasing until a wave-length again in the proximity of 1600 metres is reached, below which, similar to the reactance, it increases, more or less uniformly, at a very rapid rate, and in a manner similar to the resistance of a radio antenna. The resistance of the pair of lines at the very short waves averages about one-half of that of one line with ground return. This sudden transition in the properties of the line load is unique and is not to be entirely accounted for by the theory. The preponderance of the resistance of the line and ground load over that of a pair of lines, which manifests itself at the higher frequencies may be attributed to the more pronounced radiating properties possessed by the former type of load, at these frequencies. At the lower frequencies, the radiating properties of both systems become greatly reduced.

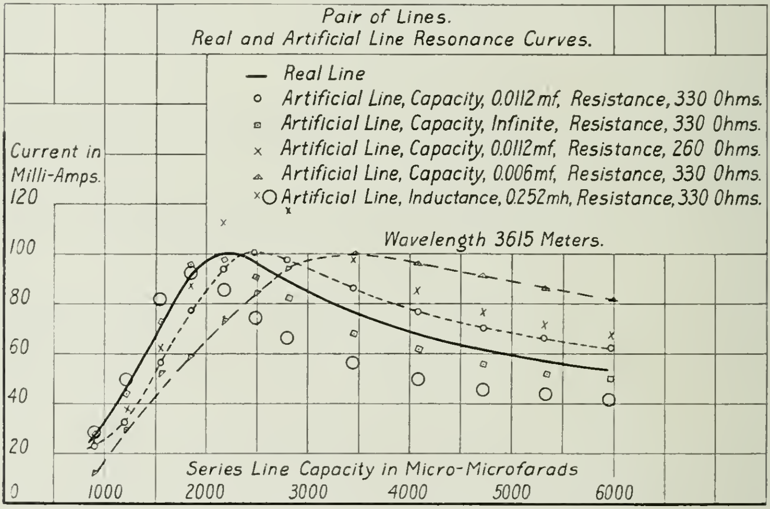
FIG. 21.



To check the accuracy of these curves and to test their validity when applied to actual practical cases, a number of artificial line loads were built up consisting of values of inductance, capacity and resistance, as nearly as possible equal to those as specified by the curves. Values of line current as a function of the series line capacity, were obtained, first for the real line load and then for the artificial line load of the constants specified. This data, plotted in the form of resonance curves for different frequencies, is shown in Figs. 21, 22, and 23.

In these figures the heavy line curves represent the current variation obtained for the real line load, and the small circle points represent the current variation obtained for the artificial load of the proper constants; the cross, square, triangle and large circle points represent the current variation obtained with artificial loads of characteristics differing from the specified ones by the amounts indicated. The agreement between real line values and those obtained on the proper artificial load is observed to be unusually exact. Any great departure from the conditions simulating the real line load causes a shift in the resonance point as well as an alteration in the shape of the resonance curve.

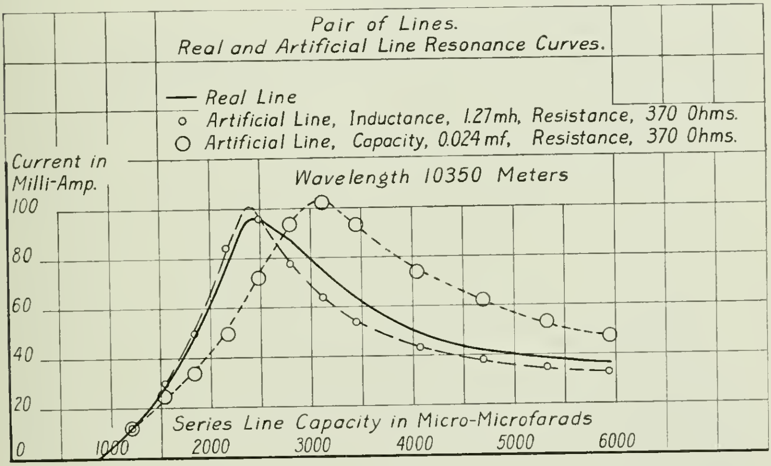
FIG. 22.



Throughout this investigation special interest, of course, has been attached to the behavior of the line load at the high range of radio frequencies, *viz.*, 1,000,000 to 200,000 cycles per second

(300 to 1500 metres), since it is within this range that the transmission and reception tests were conducted. While from the data obtained, it is always possible to construct artificial loads which will simulate the real line load in its characteristics for individual frequencies, it is both desirable and convenient, from an experimental standpoint, to build up an artificial load which will simulate at least the reactive component of the real load over a given range of frequencies. The variation in resistance with the frequency may be taken care of by a properly constructed variable resistance. From the reactance curves of Figs. 17 and 19, it is evident that for wave-lengths below 1600 metres (frequencies higher than 187,500 cycles per second), the real line load loses its distributed characteristics, and behaves as would a circuit of lumped constants. The reactance curves of the line load which obtain for the short wave-lengths are similar in shape to that of a lumped inductance, operating near its fundamental wave-length where the effect of the distributed coil capacity is appreciable. This leads to the belief that by properly choosing a value of inductance, which it is assumed to be free from capacity, and a parallel connected capacity, it should be possible to build up a circuit which would closely simulate the real line load in its reactive properties. For purposes of experimentation, over frequencies from 900,000 to 200,000 cycles per second (wave-

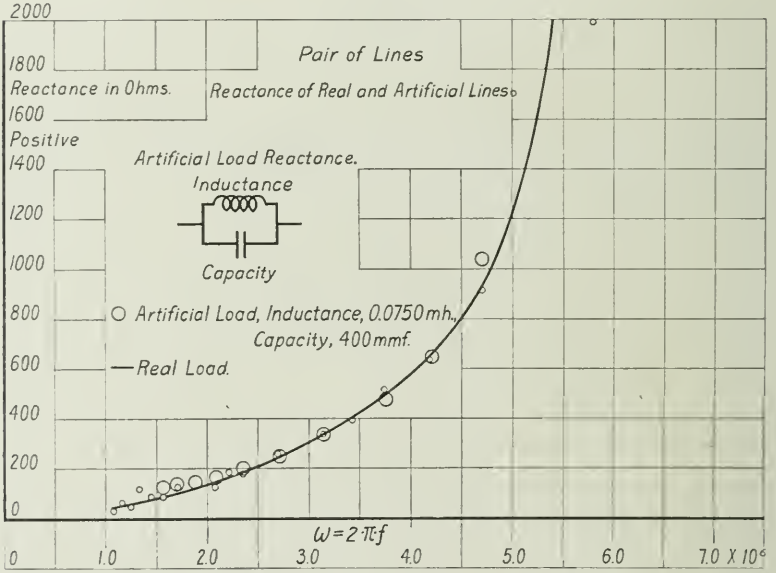
FIG. 23.



lengths 333 to 1500 metres), an artificial load has been constructed which represents the real line load of this range of frequencies.

By a method outlined by Kolster,[18] it was computed that a *true* inductance of 0.0789 milli-henrys in parallel with a capacity of 350 micro-microfarads, would give the desired reactance variation. Without resorting to extreme precision in construction, an inductance was built whose value was computed to be 0.07660 milli-henrys, and whose actual value, measured both at 1000 cycles and over the operating range of high frequencies extending up to 1,000,000 cycles per second, was 0.0750 milli-henrys. This inductance in parallel with a capacity of 400 micro-microfarads gives the measured reactance variation as shown by the large circle points in Fig. 24; the full line curve of this figure represents the reactance of variation obtained for the pair of lines plotted as functions of ω. The agreement between the reactance values of the real and artificial loads is seen to be quite exact. A view of an artificial load is shown in Fig. 25.

FIG. 24.



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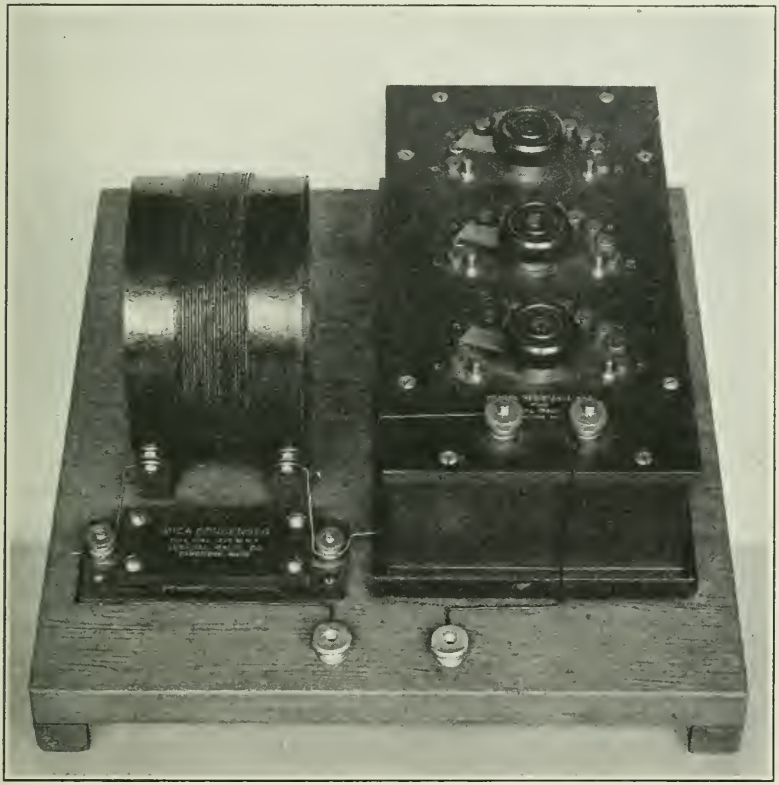
[18] Kolster: *Proc. I. R. E.*, Vol. 1, No. 1, p. 19, 1913.

VII. ACKNOWLEDGMENTS.

In conclusion, it is desired to acknowledge the active support and assistance rendered by a number of persons throughout the course of these experiments. To Major-General George O. Squier, Chief Signal Officer of the Army, original credit is, of course, given; the experiments described herein are a continuation and amplification of General Squier's original work. The hearty coöperation of the officials of the Pennsylvania and Boston and Albany Railroads, and of the New York Central Lines, and in particular of Mr. E. C. Keenan, General Superintendent of Telegraphs of the latter system, in the furnishing and movement of the two railroad coaches, and in placing the telephone lines at the disposal of the Signal Corps, has of course made the later

FIG. 25.



experiments possible; to Mr. Keenan's initiative, the commencement of the later experiments is due. In the Signal Corps party it is desired to mention the services of the enlisted personnel, consisting of Sergeants first-class Charles Murray, Fred Brennen, and W. L. Redmond. It is also desired to mention the services of Assistant Radio Engineer Samuel Isler, who throughout these experiments was in charge of the fixed station, and who coöperated with the writer in the line of impedance measurements and computations of results.

Office of the Chief Signal Officer,
War Department, Engineering and Research Division,
Washington, D. C.,
October 4, 1920.

The Mass-spectra of Chemical Elements. F. W. Ashton. (*Phil. Mag.*, November, 1920.)—The positive-ray method of analysis is extended in this paper to the elements fluorine, sulphur, phosphorus and arsenic, which appear to be made up of one kind of atom only, and also to boron, silicon and bromine, which are found to be composed of two or three isotopes. Since the examination of these seven additional elements exhausts the list of those which can be investigated as gases or as gaseous compounds it is pertinent to scrutinize the results thus far obtained. In all eighteen elements have been examined. Of these nine seem to be simple, *i.e.*, to consist of one type of atom alone. These with their atomic weights and the masses of their single isotopes as determined experimentally are as follows: Hydrogen, 1.008 (1.008); helium, 3.99 (4); carbon, 12.00 (12); nitrogen, 14.01 (14); oxygen, 16.00 (16); fluorine, 19.00 (19); phosphorus, 31.04 (31); sulphur, 32.06 (32); arsenic, 74.96 (75). It is to be noted that the ordinary atomic weights of all these are either exact integers or very nearly so. The remaining nine elements with their atomic weights and the masses of their isotopes in the order of their intensity are boron, 10.9 (11, 10); neon, 20.20 (20, 22, 21?); silicon, 28.3 (28, 29, 30?); chlorine, 35.46 (35, 37, 39?); argon, 39.88 (40, 36?); bromine, 79.92 (79, 81); krypton, 82.92 (84, 86, 82, 83, 80, 78); xenon, 130.2 (128, 131, 130, 133, 135, all somewhat uncertain); mercury, 200.6 (197–200?, 202, 204). The atomic weights of these depart from whole numbers by larger quantities than is the case in the previous group of elements.

Is it too much to expect that methods will be devised for the separation of the two isotopes of boron with atomic weights of 11 and 12, respectively?

G. F. S.

AËRONAUTIC INSTRUMENTS.*

BY

CHARLES E. MENDENHALL, PH.D.
Professor of Physics, University of Wisconsin.

The number of instruments which are of use in aircraft is rather surprisingly large, and while this article must be limited to the consideration of a few of them it will nevertheless be instructive to give a fairly complete list in which the instruments are arranged in groups in accordance with their primary purpose, but not in the order of their importance. The method of mounting some of these instruments is shown in Fig. 1.

A. Instruments for Showing Condition and Performance of Power Plant.

1. Tachometer.
2. Radiator thermometer.
3. Oil pressure gauge.
4. Air pressure gauge for gasoline system.
5. Gasoline level or supply indicator.

B. Instruments for Indicating or Measuring Airplane Performance.

6. Altimeter. } Also used for navigation.
7. Airspeed meter. }
8. Angle of incidence meter.
9. Side slip indicator.
10. Rate of climb meter—statoscope.
11. Bubble or pendulum inclinometer.
12. Gyroscopic inclinometer.
13. Accelerometer.

C. Navigational Instruments.

14. Compass.
15. Turn indicator.
16. Watch.
17. Sextant.
18. Drift meter.
19. Bearing plate, etc.
20. Ground speed meter.
21. Stabilizing devices.
22. Wireless equipment.
23. Position indicator.
24. Night landing devices.
25. Oxygen apparatus.

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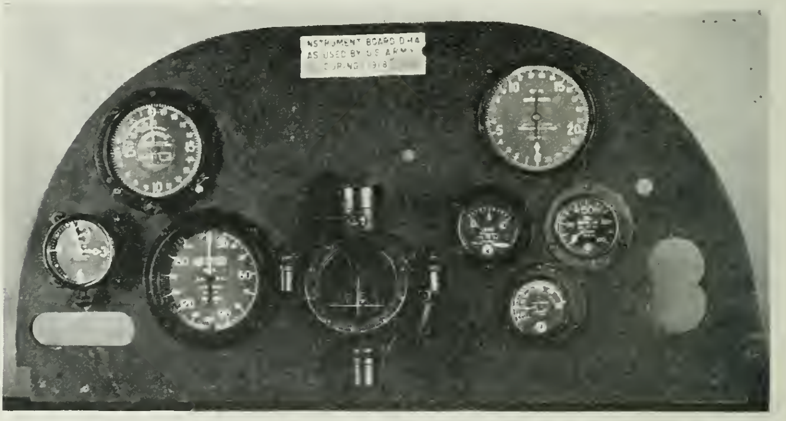
* Presented at a meeting of the Section of Physics and Chemistry and the Physics Club held Thursday April 1, 1920.

D. INSTRUMENTS FOR MILITARY PURPOSES.

26. Bombsights.
27. Gunsights.
28. Cameras.

It should be pointed out in the beginning that there are several especially adverse conditions accompanying the use of instruments on airplanes, which for some instruments become very serious indeed. These are excessive vibration, great and rapid change of temperature, large accelerations, and the necessity for keeping down weight and bulk. Other difficulties of a less general nature will be referred to from time to time.

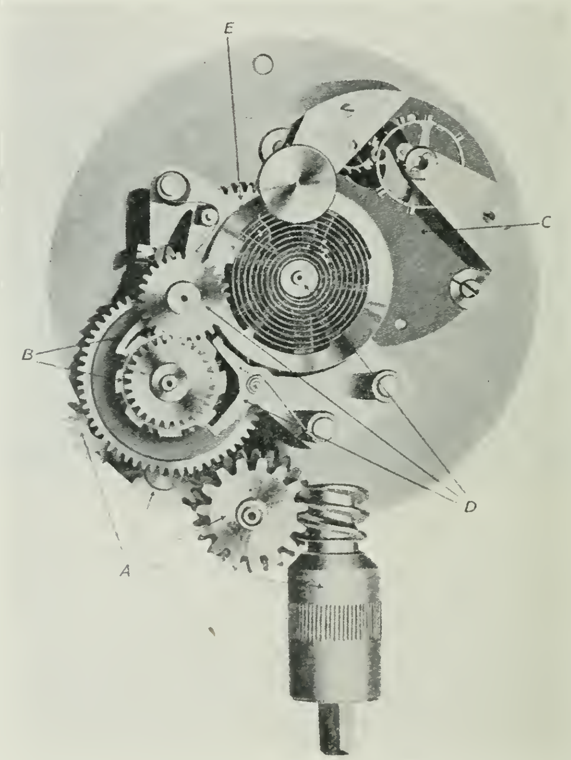
FIG. 1.



Tachometer.—The most important engine instrument is the tachometer, because it first gives warning of improper functioning, and the most successful have been either of the chronometric or the centrifugal type. The former, which has been developed largely during the war, involves two distinct but interacting elements, *i.e.*, a time-measuring device or watch mechanism containing a spring-driven escapement, and a counting mechanism containing a hand or pointer moved by the drive from the engine through either a circular or linear rack. The hand is turned at a speed proportional to the engine speed for a fixed interval of time determined by the escapement. Hence the angle through which the hand is turned will be proportional to the engine speed. At the end of this motion the hand is locked in position, while the driving mechanism returns to the initial position and the cycle starts over again. If the engine speed is increasing the mechanism operating the hand will be turned farther during the next driving interval, and at the end of this interval the hand will be pushed ahead and again locked. If the speed is decreasing the hand will drop back, while if the speed is constant the hand will be again locked in the original position. Thus the cycle of operations consists of a driving interval, an interval during which the hand is adjusted to the new position of the driving mechanism, the locking of the hand, and the return of the driving mechanism to the zero position. In some instruments this complete cycle takes one second, in others two, the hand being reset each second or every two seconds as the case may be. The number of teeth on the rack of the driving mechanism which controls the position of the hand obviously determines the smallest interval to which the hand can respond as the locking arm must engage one tooth or the next, but this can be easily made less than 5 per cent. of the normal reading. The chief inherent difficulties of this type may be said to be liability to wear and breakage due to multiplicity of parts, many of which have to be continually started and stopped, and a tendency of the hand to jump back and forth through the interval determined by a rack tooth.

In 1917 there were two tachometers of this type in use abroad, the "TEL" having a relatively heavy and substantial mechanism, and the "JAEGER" built more like a clock or watch. Operating under the TEL patents the National Cash Register Company later produced many thousands of instruments for the Air Service, while a new and excellent instrument was designed by Mr. Prouty and produced in large numbers by the Van Sicklen Company. Fig. 2 shows the internal mechanism of the latter form. In 1918 the Hamilton Corporation completed the development of a third form which has one novel feature, namely, that the instrument is driven by air pulses produced by a compact reciprocating pump attached to the engine and transmitted through stiff-walled rubber tubing about ⅝″ outside diameter. This question of drive is of particular importance in installations on large machines, in which it may take 35 feet or more of the usual flexible shafting, used with all mechanically driven tachometers, to connect the engine with the indicating head on the instrument board. Such a length of flexible shaft, especially when very much bent, as will unavoidably be the case, has the disadvantage of absorbing very considerable power, of wearing rapidly, and of providing opportunity for the core or shaft proper to pull away from the end connections (which must be slip connections) unless the length of core is adjusted for the bends of each particular installation. For such cases the air-driven type is of considerable promise.

FIG. 2.



The centrifugal type of tachometer, the more common in ordinary use, has also been largely used for air work, both in this country and abroad, a number of types being developed for this purpose, some of most excellent performance. There may be mentioned the Jones, Reliance and Johns-Manville. An instrument of this type was developed in 1918 by Doctor Washburn of the Bureau of Standards, as the result of extended tests, but did not reach the production stage.

The chief inherent difficulties with tachometers in general are perhaps those of wear and lag (lost motion), both of which demand for their reduction good design, good workmanship and good materials. At first sight it might appear that the centrifugal type would give more nearly instantaneous readings than the chronometric, which responds only every one or two seconds, but such is not the case. Since its moving system has considerable inertia and rotates at high speed it requires an appreciable time to adjust itself. While this is a disadvantage in one way, it smooths over small fluctuations in speed and gives a steadier hand.

The very common magnetic type of tachometer has not been satisfactorily developed for air use; nor has the electric, though the latter offers some advantages in the case of long transmissions on large planes. Several air-viscosity types, and an airflow type were experimented with, but never brought to a production stage.

Radiator Thermometer.—The conditions of use here demand a distant-reading instrument, and two types are used. One involves a "bulb," containing a liquid whose saturated vapor pressure is transmitted through a tube to an indicating head or pressure gauge; the other a "bulb," connecting tube and pressure head, all filled with a liquid, whose relative expansion produces the pressure change which is measured. For the former type ethyl ether, sulphur dioxide, or methyl chloride, may be used, for the latter alcohol is commonly employed. In both cases temperature compensation of the pressure head is needed, while for the vapor pressure type the volumes of the bulb, tube, pressure head, and the amount of liquid must be so proportioned that the *meniscus* is always in the bulb, and hence is at the temperature to be measured. If there is too little liquid it may entirely evaporate from the bulb when the latter is the hottest part of the system, and if there is too much it may more than fill the bulb if this is the coldest part of the system, the meniscus being somewhere in the tube.

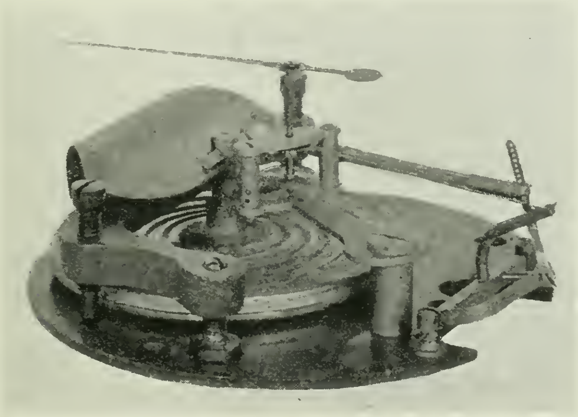
With the liquid-filled type, it is important that the volume of the tube and instrument should be small compared to that of the bulb, in order to reduce errors due to changes in volume of the former. Both types are subject to an error due to change in barometric pressure with height or otherwise, which is of course smaller the higher the internal pressures which are used. Thus an ether vapor pressure thermometer will at 20,000 feet indicate about 3° high, but this is not a serious matter; with a liquid-filled thermometer this error may be very much less. Since the purpose of the thermometer is to warn of overheating of the engine, and possible freezing of the cooling water, no great accuracy is required.

Oil and Air-pressure Gauges.—Since there is usually a forced circulation of lubricating oil, a simple pressure gauge will suffice to show whether the oil pump is functioning properly and the circulating pipes free, and the oil not too cold and viscous to flow properly. If, as is still commonly the case, the gasoline is fed by air pressure, a simple air-pressure gauge is provided to indicate when a proper air pressure is being maintained above the gasoline in the fuel tank. For military use, however, the pressure feed system was being displaced as rapidly as possible, because of the inherent danger: a puncture resulting in a particularly vigorous leak on account of the five or ten pounds' pressure which was used.

Gasoline Level Indicators.—A similar argument of increased danger applies against a certain type of gasoline level indicator which appeals to a physicist because of the simple application of hydrostatic principles. In this case a pressure gauge is connected to a tube extending to the bottom of the fuel tank; through this tube air is forced by a hand or power pump. Obviously the maximum air pressure which can be obtained is that necessary to force the air out against the pressure of the gasoline at the bottom of the tank. This pressure is of course proportional to the depth of gasoline, and the pressure gauge can be graduated to read inches of depth. By making the case of the instrument air-tight and connecting it to the top of the tank, the scheme may be adapted to a pressure feed system. Though this gauge was made and used to a certain extent in France, it has never been adopted in this country. The usual gauge is of the float type, and there are two rather troublesome problems involved: first, the design of a simple rugged float system which will not stick or jam, and second, the transmission of the float motion, as is in some cases necessary, some considerable distance to the indicating head. When the latter is directly in the tank the problem is much simpler, and there are doubtless many mechanisms which will work, but it is equally true that many more have been designed which will not work. At least two fairly satisfactory ones were developed during the war—the Tanner and the Cole—the latter having a transmission system copied from an old-fashioned house bell; a similar transmission mechanism was also used by the Germans.

Altimeter.—This is of course merely the familiar aneroid barometer, the essential features (see Fig. 3) being a more or less perfectly exhausted flat metal box with corrugated elastic sides, one of which is rigidly attached to the case, the other moving as the external pressure changes. Various types of mechanism are used to magnify this motion, the ultimate result in our standard instruments being a complete rotation of the pointer for a change of pressure of about 4 cm. of mercury, corresponding to a height of 20,000 feet, with a uniform scale.

FIG. 3.



Mechanism of altimeter.

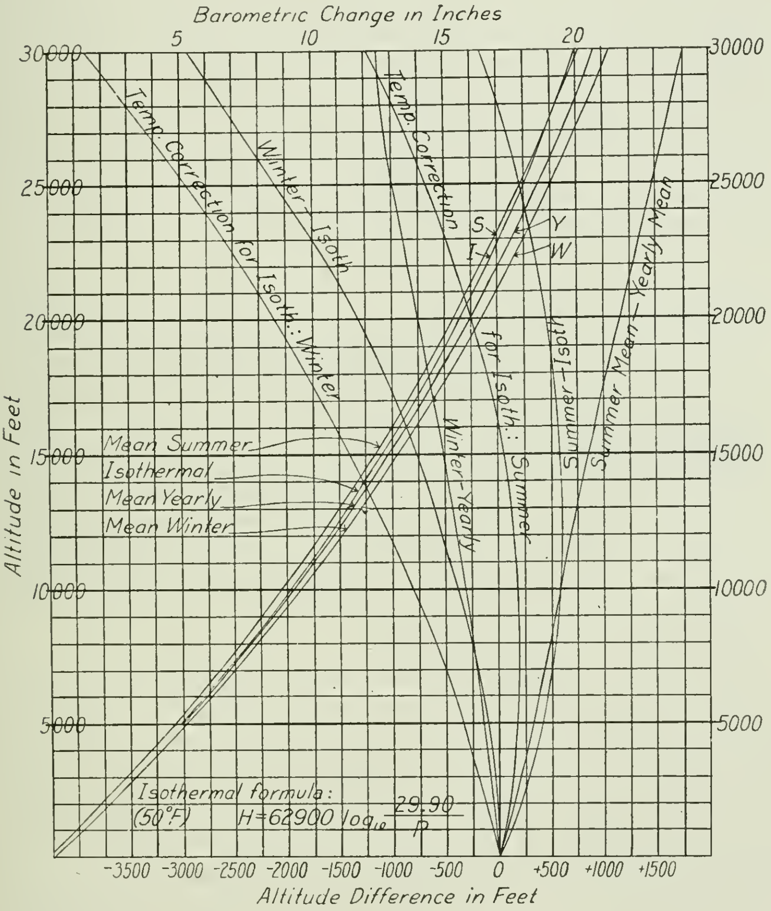
Since atmospheric pressure does not vary in simple inverse relation to altitude, the production of a uniform scale demands a specially designed mechanism involving either a cam, or more commonly levers, whose effective arms vary from point to point on the scale. The difficulties are of two sorts: First, those of the instrument considered as a pressure measuring device, and second, those involved in the relation between pressure and height. Of the first class may be mentioned elastic after-effect, "sticking," and temperature error, of which the first is the most difficult to reduce. The restoring force which acts in opposition to the external pressure on the cell is due in part to the elastic forces of the cell itself and in part to an external or internal spring, which may be of the best quality of steel. The cell is usually made of nickel-silver, more subject to elastic after-effect; hence it is desirable to proportion the cell so that as much of the restoring force as possible may be due to the spring. A systematic study of the elastic properties of alloys suitable for cell construction, as a function of the composition and method of manufacture (heat treatment) was undertaken by the Bureau of Standards and the Air Service coöperatively, and has been continued by the former. The results of this may lead to considerable improvement.

The avoidance of "sticking" of the mechanism depends largely upon good workmanship and simplicity of design, while temperature compensation may be partly attained by imperfect exhaustion of the cell and by the introduction of an element into the mechanical train whose thermal expansion compensates the thermal-elastic changes of the spring and cell.

Granted the attainment of a satisfactory pressure-measuring instrument, there remains the calibration of it to indicate height. This is now universally carried out by means of the equation $H = 62900 \log_{10} \frac{29.90}{P}$ in which H = height in feet and P = atmospheric pressure in inches of mercury. This equation is based on the assumption of an isothermal atmosphere at 10° C., and the corresponding average humidity, and neglects the small variation of "g" with height. The assumption of an isothermal atmosphere is of course erroneous, and it is worth while considering the magnitude of the errors involved and the possibility of allowing for them, as well as the question whether a better basis for calibration could not be used.

The diagram (Fig. 4), based on computations of Lieutenant Waterman of the army Meteorological Service, using data published in the *Monthly Weather Review*, January, 1918, by W. R. Gregg, shows the magnitude of the errors to be expected on the basis of the observed average summer, winter and yearly temperatures, with an instrument graduated on the usual isothermal basis. One may conclude from Fig. 4 and similar curves for spring and fall, that the error in fall, winter and spring would be very considerably less if altimeters were graduated in accordance with the yearly mean temperature distribution, while the errors in summer would be increased at high altitudes.

FIG. 4.



Aside from the *average* errors to which Fig. 4 refers, there are errors due to the departure of the temperature distribution from that assumed in calibration, whether this be the isothermal, as usually assumed, or the yearly or summer mean. Such variations from the mean are very common at lower altitudes, but are not likely to extend as high as 10,000 ft. Lieutenant Waterman concludes that the maximum error of this sort is perhaps –500 or –600 ft. at 3000 ft.

The only way of reducing the very considerable[1] temperature errors which are likely to occur with any fixed calibration (unless one used three separate dials, for summer, winter, and spring and fall) is by applying a temperature correction. If observations of air temperature are taken at the ground and at the maximum elevation, and better, at several intermediate levels as well, a correction may be taken from tables, such as have been published, for example, by the Bureau of Standards. In this way it is possible to reduce the outstanding error, as estimated by the Bureau of Standards, to one-half of 1 per cent. Since ground temperatures are subject to great local irregularities, it is the usual practice to observe at 5000 ft. and use the empirical relation $t_g = t_{5000} + 7^\circ$ C., which is accurate enough for moderate temperatures. Some work has been done in England and is now being initiated in this country, upon the development of an instrument which would automatically correct to some extent for the main temperature error, by utilizing the temperature changes in the instrument during the climb, assuming that it took the temperature of the air at each level, or at least at the ground and the final height. This is a very interesting problem, and it would seem possible to make some progress toward a solution, but I have not heard of any final results.

The universal method of correcting for fluctuations in barometric pressure by having a rotating dial, which is always set to "zero" just before leaving the ground, is only approximate, since in general barometric fluctuations are not proportional to the pressure gradient at successive heights, but is good enough for daily changes, which are greatest near the earth. For a permanent shift, say to a higher landing field, the scheme of shifting the zero of a uniformly graduated dial makes the desired correction at all heights, in so far as the calibration of the instrument is itself correct.

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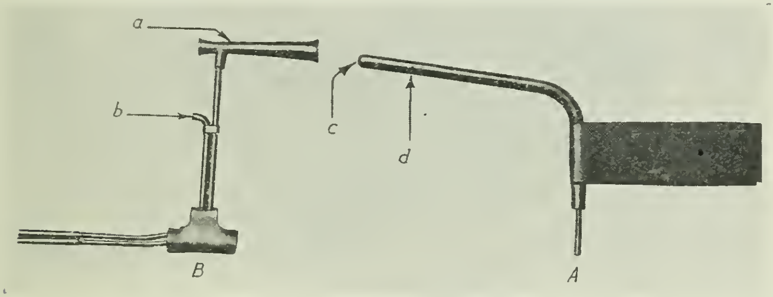
[1] It is obvious that the careful application of the temperature corrections is necessary in deciding as to all altitude "records." For a discussion of this aspect of the recent flights of Messrs. Rohlfs and Schroeder see *Science*, April 9, 1920.

Obviously the altimeter, because of inaccuracy and lag, is of no use in landing, except in a general way, but it gives an essential element in the determination of ground speed, for use in bomb-dropping, and as our knowledge of upper air currents increases, it will be used in locating favorable wind-levels, especially when flying above clouds.

Airspeed Meter.—The relative motion of an airplane with respect to the air is an essential factor in determining its stability, and the airspeed meter is used to determine the component of this motion parallel to the axis of the machine. This statement is really inaccurate and will now be corrected, for which purpose a digression is necessary. The motion of the plane through the air develops a complicated set of forces of which those on the struts, wires, side surfaces, etc., are in the line of motion, and of the nature of a resistance to motion (R), which varies approximately as the square of the speed, S, and as the density of the air. Besides these there are the forces on the wings and certain portions of the fusilage which, besides having resistance components parallel to the motion, also have large components perpendicular to this, the resultant of which is called the "lift" L, which also varies approximately as S^2d, where d is the density of the air. The remaining forces acting are the weight W, and the thrust of the propeller T. For certain values of W, T, R, and L, the plane will be capable of stable motion with uniform velocity. Since R and L vary approximately as S^2d, we may conclude that, assuming W and T fixed, corresponding conditions of motion at different altitudes will correspond to fixed values of S^2d.

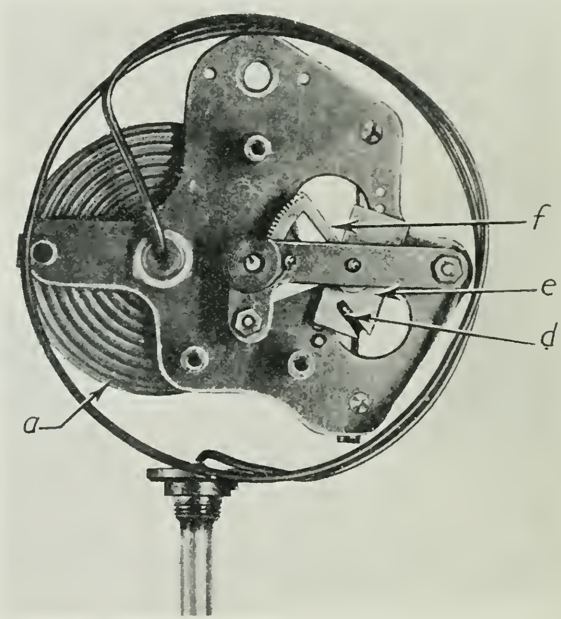
FIG. 5.



A, pitot tube, Sperry type; *B*, Venturi-pitot tube, army type. (Bristol Co.)

Hence, it is desirable to have an instrument which gives, not a given reading for the same relative air speed at all heights, but one which gives the same reading for the same value of S^2d, at all heights. The actual air speed would then be proportional to observed speed over d. The particular conditions of motion which are of special importance to the aviator are: the best condition for climbing and gliding, most economical speed for level flying, and the stalling conditions, though the latter can be well enough determined by the "feel" of the ship.

FIG. 6.



Mechanism of air speed meter (Bristol type).

For assistance in handling the plane, since true air speed is not desired, the most common instrument is either a pitot or a venturi tube, or the two combined, as shown in Fig. 5. These must be combined with an instrument for measuring pressure differences (see Fig. 6), consisting of a mechanical magnifying system and some sort of diaphragm; with the pitot tube, one side of this diaphragm is exposed to the "static" pressure, the other to the "impact" pressure, by air-tight tubes running from the "head" to the indicating instrument. In the case of the pitot-tube, theory (which is admittedly only fairly satisfactory) indicates that the pressure difference produced will be equal to S^2d, and this has been confirmed as regards the S^2 factor over a range of moderate speeds by observations with a whirling arm at the National Physical Laboratory, London. In fact, the pitot tube is at present the basic absolute standard for practically all airspeed measurements, both in the open and in wind tunnels. For high speeds (over 130 m.p.h.) a correction is required according to theory because of the compressibility of the air (see Buckingham 1st Rep. Am. Nat. Adv. Com. for Aeronautics), but further experimental research in this connection is desirable. The venturi tube produces a suction which, if the flow through the tube were non-turbulent and the compressibility of the air were negligible, would, according to Bernoulli's theorem, also satisfy the relation of $p_1 - p = KdS^2$. Unfortunately, neither of the above assumptions hold, so that the "theory" of the venturi tube is of no practical value except to indicate that probably the variation in proportion to d may be somewhere near the truth. The Bureau of Standards has recently obtained experimental evidence on this point. It is possible to design a venturi which will satisfy the S^2 law for a certain range of speed as was first done by Doctor Zahm. This was the first tube adopted by the army. Later, Lieutenant Oliver and the writer, working at the Bureau of Standards, designed another tube which followed this law through a still wider range (up to 150 m.p.h.) and was only of one-half the size and had less than one-quarter the head resistance. This and the English standard Pitot are shown in Fig. 5, where *a* is the Venturi tube and *b* the corresponding impact opening, *c* the Pitot and *d* the static openings.

The pitot tube has the advantage of simplicity and ease of manufacture, since almost any sort of a forward-pointing tube will do. On the other hand, quantity production of the venturi-pitot combination, shown in Fig. 5, was found easily practicable, and since it can be made to give at least five times the pressure difference at any given speed, a more rugged pressure measuring instrument may be used. It was for this reason that the venturi-pitot was adopted by our Air Service. For seaplane use it has the additional advantage of being less liable to plugging by splashing water.

In another form of airspeed indicator a plate is exposed normally to the air stream, held in position by a spring whose compression, due to the impact pressure, is indicated in a dial. If provided with a sufficient guard plate, at the cost of increased head resistance, such a plate will, as Zahm showed, give pressures agreeing with a pitot tube. Without a guard ring the agreement will be only approximate. Another form of instrument which must be mentioned consists of some form of screw or cup anemometer, whose speed of rotation may be indicated by some form of tachometer attached either directly, or else through electrical or mechanical transmission to the cockpit. This gives true and not effective air speed, and hence is not so convenient from the standpoint of handling the ship. On the other hand, for use in dead reckoning and for bomb dropping its readings are what is wanted, while the readings of the other type of instrument must be corrected for altitude.

It should be emphasized that the location on the plane of the venturi or pitot tube, or plate or screw, is of great importance. The airflow is so much disturbed in the neighborhood of the wings that it is usually impossible to observe correct air speeds unless the tube or head is held several feet in advance of the leading wing and well away from the screw and fusilage. Such a position being impracticable in general on account of the increased head resistance of the mount, a " plane correction " should be determined for each type of plane and position of mount by speed-course trials. As regards use in handling the plane, absolute values are not needed, constancy of calibration being more important.

Angle of Attack Meter.—The angle of attack is the angle between a wing chord and the line of flight. For horizontal flight there is just one air speed possible for each angle of attack, hence the angle of attack has sometimes been used in place of air speed in handling the plane—notably by the Wrights. Since this angle is in general small, instruments have been designed for magnifying it and indicating it to the pilot, but have not come into much use. A string or tape whose end plays over a graduated arc is a simple but fairly effective device.

Side Slip Indicator.—One form of this consists of a small metal sphere provided with two small holes at the ends of the horizontal transverse diameter, which are connected (internally) with the two sides of a sensitive differential pressure indicator. If there is a side slip, that is, if the relative air stream is *not* normal to the transverse diameter, a pressure difference of one sign or the other will be produced. If the holes are at the ends of a vertical diameter the instrument becomes a form of angle of attack indicator. In neither capacity is the instrument much used.

Statoscope.—The purpose of this instrument is to indicate when a plane is rising, falling or flying horizontally, and it is chiefly used in performance tests. The usual form consists of a thermos bottle, which can be quickly opened to or cut off from the external air by means of a stop-cock, and a scheme for indicating, or measuring, the pressure difference between the inside and outside, such as a U-tube pressure gauge containing oil. If the external pressures are equalized and the stop-cock shut at any height, then a rise or fall of the machine will be shown on the gauge as a decrease or increase of the external pressure. By this means the absolute height, so far as it is determined by constant external pressure, may be kept constant within 10 feet. A less sensitive form of instrument on this principle has been put on the market.

Rate of Climb Indicator.—If the above form of statoscope is provided with a capillary opening in place of the stop-cock, it becomes a rate of climb indicator, an absolute instrument in so far as atmospheric conditions are constant and normal. The approximate equation of the instrument is

$$\frac{d}{dt}(\triangle p) = K \triangle pP - \frac{P}{A}\frac{dH}{dt}$$

where

$\triangle p$ = pressure difference between inside and outside of flask.
P = barometric pressure at height H.
K = constant depending on size, etc., of capillary opening.
H = altitude.
A = a constant in the assumed isothermal equation connecting altitude and pressure.

If Δp is maintained constant then

$$\triangle p = \frac{1}{AK}\frac{dH}{dt}$$

which will be independent of altitude. That is, a constant pressure difference corresponds to a constant rate of climb. Experiments of Captain Webster's showed that readings could be made accurate to about 20 ft./min., with a capillary such that a new steady reading would be reached in about 5 or 10 seconds after a change in elevation had occurred.

Bubble or Pendulum Inclinometer.—In a properly-banked turn an airplane tips so that the resultant force compounded of gravity and the central acceleration, is normal to the floor of the plane, *i.e.,* bears the same relation to the plane that gravity does in straight horizontal flight. For a 60° bank, therefore, we have the relation that

$$Ac = \text{central acceleration} = \frac{S^2}{R} = g \tan 60^\circ = g\sqrt{3}$$

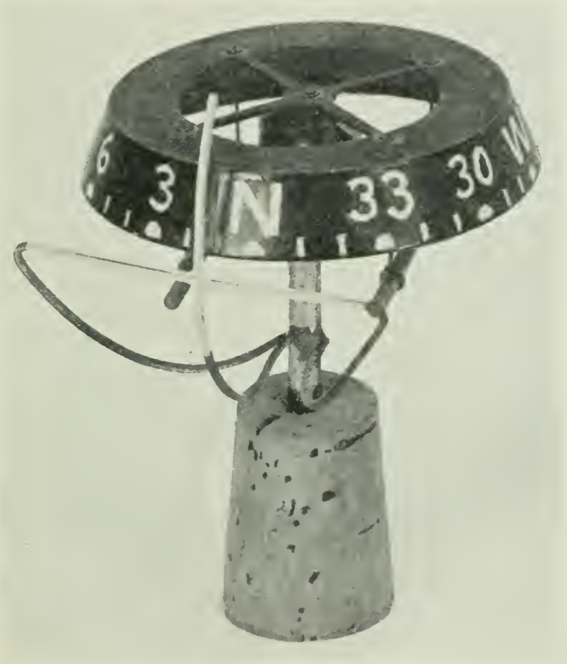
$$\text{and } g' = \text{apparent gravity} = g \sec 60^\circ = 2g$$

Any instrument, such as a level or pendulum, which responds quickly to gravity, will therefore remain in its symmetrical or zero position during a bank and be useless as an inclinometer. Either of these devices will show a deviation, however, when a plane is not properly banked and is therefore side-slipping, and hence are of some use as indicators of *incorrect banking.* As a matter of fact a measure of the angle of bank is of no general use, though an instrument which will show when a plane is turning, and therefore usually banking, is of great use and will be discussed later. Under certain circumstances a really effective inclinometer might be of use when it is desired to fly with as even a keel as possible, and for such use a variety of gyroscopic devices have been tried. The underlying principle of these will be taken up later, but one or two may be mentioned. The simplest, though in many ways the least satisfactory, is the gyroscopic top of Garnier. This is a heavy top supported very near the centre of mass on a steel pivot point, which rests in a steel or agate cup, mounted in a closed case with a spherical glass top centred at the pivot, and driven by air jets playing against the rim of the top. Strictly speaking, it is not a top, for the point of support is usually very slightly above the centre of mass. Speeds of 5000 to 10,000 r.p.m. may be obtained with an air pressure of only a few centimetres of mercury, and displacements of the top with respect to the case are read on graduations on the glass cover. It is a very pretty thing, but is too susceptible to the jars of ordinary service, and has besides several serious inherent troubles; its use has therefore not been found worth while.

Navigation of Aircraft.—The primary requisite in navigation is the ability to steer a straight course in a known direction; hence we may well introduce the subject by considering the two instruments which are designed to make this possible.

Compass.—The only practicable compass so far developed for air use is the magnetic (see Fig. 1 for standard army type), though there have been reports that a gyroscopic type will be made available. For various reasons the compass has been perhaps the most discussed and most abused instrument, chiefly because it has been expected to do two things: first, to give the direction of a maintained course; second, to indicate departures from this course. The first duty it can fairly well perform, but as we shall see, it is ill adapted to the second. A compass card of the usual type (see Fig. 7) is supported upon a pivot attached to the card, with the point slightly above the centre of mass, and has the equivalent of a counter-balancing weight on the south side to overcome

Fig. 7.



the couple due to the vertical component of the earth's magnetic field. In order to diminish the effect of vibration it is necessary to reduce as much as possible the pressure of the pivot on the supporting cup, and to do this and also introduce desired damping, the cards are immersed in a liquid, either alcohol or kerosene. The forces acting upon the card are the following:

Gravitational and accelerative forces upon the symmetrical mass of the card.

Gravitational and accelerative forces upon the counter-weight.

Gravitational and accelerative components of the buoyant forces on the card.

Viscous forces between card and liquid.

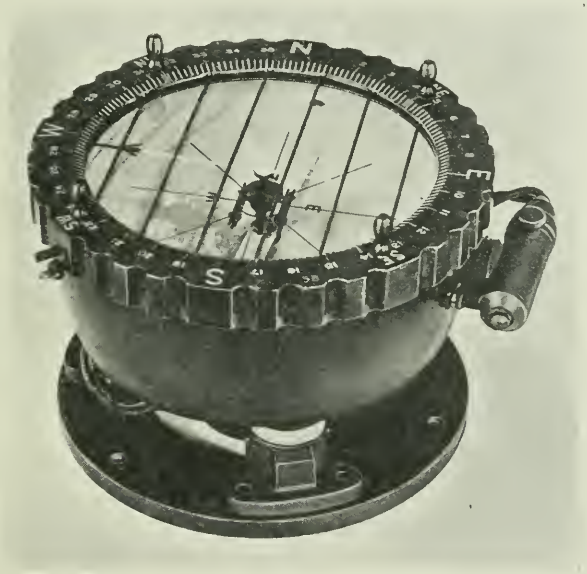
Magnetic forces on the card.

The resultant motion has been most carefully analyzed by Lindeman, and while the general equations of motion cannot be integrated his discussion of the initial motions leads to conclusions verified by experiment and indicate how to minimize certain unavoidable faults.

His first conclusion is that the card will always set its plane very nearly normal to the "apparent gravity" on a bank. This being true, simple considerations suffice to prove the existence, though not the magnitude, of the most troublesome characteristic of the compass, the so-called "northerly turning error." If one considers a plane taking a bank to turn from a north course toward the west, it is readily seen that the banked card will have a magnetic couple acting on it, tending to turn the card in the same sense in which the case which carries the reference or "lubber" line is turning. The same thing will hold for a turn from north toward east, and it is found that under some conditions the card will turn farther than the case, thus indicating a turn in the *wrong direction.* For a plane turning out of a south course, the card will turn in the opposite direction to the case and hence will exaggerate the amount, though this cannot lead to uncertainty as to the sense of the turn. Ambiguity only occurs for a turn out of the north. Lindeman's final conclusion is that under ordinary conditions as to speed a card having a period of from 40 to 60 secs. will not indicate a wrong turn, whereas with a period of 20 secs. or less the wrong turn will be shown.

The first experimental study of the behavior of airplane compasses, with approximate discussion of the cause, was carried out by the late Keith Lucas, who pointed out that, because of the lack of symmetry of the card, there is an accelerative force tending to make the south (counterweighted) end of the card point *away* from the axis of a turn. This conspires with the magnetic couple referred to above, and becomes very pronounced in a spin. If this is eliminated by using a symmetrical card with double pivot, the magnetic effect is sufficient to produce an ambiguity. The errors we have been discussing are only troublesome in case the compass is the only means of maintaining a straight course, in fog, or cloud flying, and then they will be exceedingly dangerous. While there is no doubt of the advantage of a long-period compass (R.A.E. Mark II, for example) as regards northerly turning error, it has the disadvantage of a slower recovery, and for this reason has not been as extensively used as it otherwise would have been. Fig. 8 shows the most recent English compass, the aperiodic, evidently designed to combine the advantages of the two types, in which the mass of the card is reduced to a minimum and the damping relatively increased. I have seen no reports of its behavior.

FIG. 8.



Some early English reports laid great stress upon the desirability of having a perfectly spherical bowl in order to reduce the disturbing effects of currents in the liquid produced by rotation, but our experiments, and I think the later English ones also, showed that this was of relatively little importance.

There are still to be considered two most troublesome matters, the disturbance due to vibration and to magnetic fields on the plane. Vibration may not only produce a very annoying motion of the card, interfering seriously with the accuracy of reading, but also a steady deflection of from 2 to 15 or more degrees, depending upon the nature and amplitude of the vibration, the method in which the compass bowl is supported, the shape of the pivot and cup, the form of the guard and the net weight on the pivot. The bowl must be supported so as to maintain its alignment and at the same time to permit a damped motion with respect to the ship. An elastic support without damping will not do. A compass which will work upon one plane may not work upon another, as we found to our cost. It is not necessary to go into these details but they must be studied carefully for each type of installation.

The magnetic troubles must also be studied for each type of plane and position of the compass, as they depend on the location of iron parts, and upon the type and position of the ignition mechanism. Compensation of the magnetic field due to the plane is very difficult, as they are likely to vary from time to time, and are partly due to induced magnetization which varies with the heading of the plane. This is particularly true of the pilot's cockpit next the engine of a high-powered plane having a battery-ignition system. It is desirable to check the results of " swinging ship " on the ground by tests in the air to determine compensation and vibration errors, and this requires special methods. Perhaps the simplest is by the use of a stabilized horizontal graduated circle with a vertical wire at the centre, the position of whose shadow on the circle can be read off. This gives the apparent bearing of the sun with respect to the axis of the plane and from this, knowing the day and hour, the true bearing may be computed and compared with the compass bearings taken at the same time. Mr. Sterling demonstrated the accuracy of this method in many of our tests.

Turn Indicator.—While this instrument has not yet come into general use, it is sure to be of the greatest importance, for it relieves the compass of the second and most difficult demand upon it, assistance in holding a straight course. Two types have been developed: the first, depending upon the difference in air speed of the two wing tips during a turn; the second, using gyroscopic precession. In the first case two pitot tubes may be mounted, one at the tip of either wing, connected to a differential pressure measuring instrument in the cockpit. It works out that the difference in impact pressure between the outer fast-moving wing and inner slow-moving wing tips is just twice the outwardly directed centrifugal pressure difference in the connecting tubes due to the rotation, hence the net pressure difference available for measurement is equal to the latter, and is quite small in amount. On a banked turn this is slightly reduced because the outer wing tip is at a higher level. A more sensitive arrangement would be to use venturi tubes in place of pitots, and we experimented quite a little with such an arrangement at Langley Field. In either case it is desirable to pivot the tubes and provide a tail vane so that they head into the air stream. At best the venturi tubes, and to a less extent the pitot, gave irregular and fluctuating indications, and as regards sensitiveness, convenience, and small head resistance the gyroscopic type is much superior.

Work with the gyroscopic type in this country was started by Dr. A. H. Compton, working in conjunction with the Air Service, on a device originally intended as a gyroscopic inclinometer,[2] but which proved to be unsatisfactory for this purpose and was redesigned for a turn indicator. We had been anticipated, however, by Prof. J. B. Henderson in England. The essential feature is a gyroscope mounted with its axis parallel to the floor of the ship, and arranged so that if, due to the turning of the airplane, one attempts to turn the gyro axis around a vertical axis, it will precess around a horizontal axis and thus indicate the sign as well as the rate of turning. To control the motion of precession, springs are provided which tend to keep the gyro frame symmetrical with respect to the case, and also some form of damping. Several forms of drive have been tried for the gyro, an airscrew with flexible shaft, air jets, and Doctor Henderson's form in which the rotor is itself the airscrew. With proper design extreme sensitiveness may be obtained, so that small angles of bank may be considerably exaggerated, and of course the instrument will indicate unbanked turns as well. The design which we worked out, shown in Fig. 9, is perhaps the lightest and simplest, and most flexible, since the indicator may be placed at any convenient place, the small suction venturi being preferably in the slip stream. Doctor Henderson's is more rugged and has the advantage of being in a single unit. Furthermore, by the use of some form of integrating device he proposes to show the total change in course which has occurred since the last setting of the instrument. The value of a turn indicator in cloud or night flying is obvious, as it enables the pilot to fly straight, avoiding the turns and spirals which throw a compass out of commission. A turn indicator and a properly installed compass form a strong combination.

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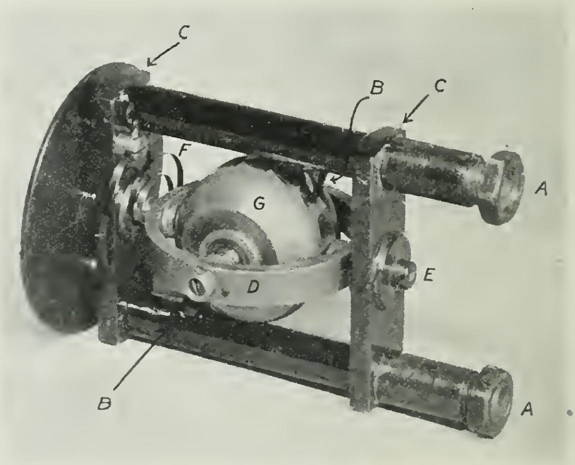
[2] The Germans also developed a gyroscopic turn indicator, combined with an inclinometer, which appears to be based on the same idea which occurred to Doctor Compton and which did not prove satisfactory as an inclinometer because so sensitive to lateral accelerations. A German instrument of this sort is now in the possession of the Bureau of Standards.

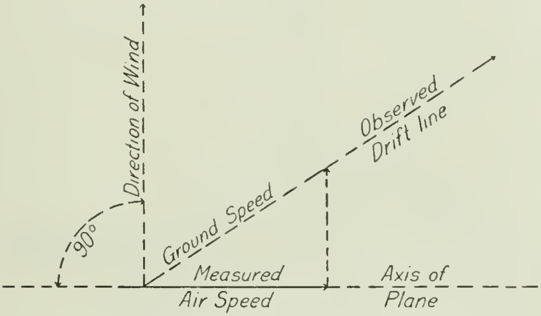
FIG. 9.



Turn indicator: The frame is hollow and carries air through the openings *AA* to the jets *BB* which drive the gyro *G*.

Turning now to the general problem of aerial navigation, it is obvious that it differs from that of ordinary navigation in two important respects: first, the addition of the third dimension, and second, the high velocity of the currents (winds) in which the vessel is moving. The method of handling the third dimension, altitude, has already been discussed, and the significance of the second factor must now be considered. Navigation in general may be carried on in two ways—either by the independent determination, by astronomical or wireless observations or otherwise, of successive positions, or by attempting to determine the *change* of position from a known starting point, *i.e.*, "dead reckoning." The latter involves determining the direction of a course with respect to the ground and the speed over the course. In sea navigation the velocity of the currents (which correspond to the winds in the case of the airplane) is usually small compared to the ship's speed, and hence easy to allow for. On the other hand, in the case of air navigation the wind velocity may be as high as that of the plane, so that the speed with reference to the ground (ground speed) may be quite different from the air speed, and the direction of the "course made good" (with respect to the ground) quite different from the "course steered" (axis of plane, assuming no side slipping). It is therefore *essential* for "dead reckoning" that the ground or the sea should occasionally be visible in order that the ground speed may be measured and the ground course, called line of drift, be determined by using some form of drift meter.

FIG. 10.

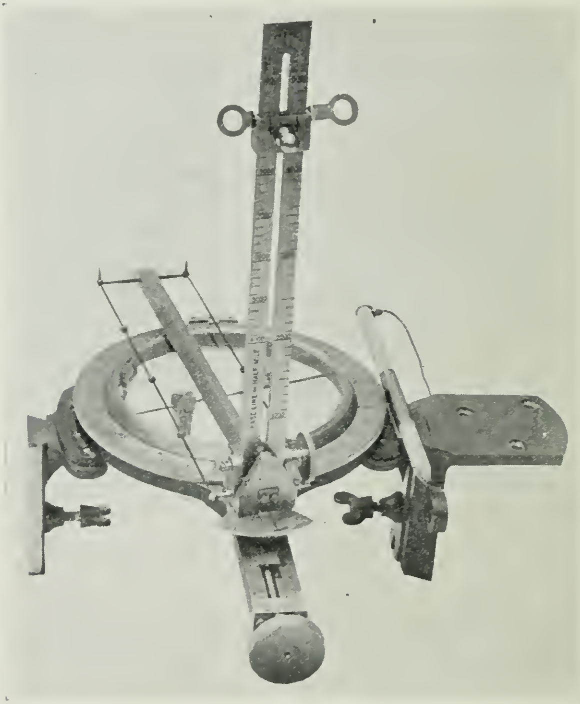


Drift Meter.—This may involve a wire, or series of lines on a glass plate, which can be rotated with respect to the plane axis until parallel to the apparent motion of objects on the ground, the angle of the line of drift with respect to the axis of the plane being then read. Or a series of radiating wires may be used whose angle with respect to the axis is known, as in Captain

Webster's device, so that one can note the line along which objects drift. With the latter form the drift angle may be determined to 1°. At the same time the compass reading must be noted, and from these two the bearing of the drift line, or course made good, is at once obtained.

The ground speed may be determined in several ways, one of which is as follows: First, head the plane so that the drift is parallel to the axis, *i.e.*, fly up or down wind. Then, using the compass to determine the angle, turn and fly at right angles to the wind and determine the drift angle. We then have a triangle (Fig. 10) for the mechanical solution of which several very ingenious devices have been designed, of which those of Major Wimperis may be particularly mentioned. The procedure of flying along and at right angles to the wind would in general involve considerable departure from any given course, which it is

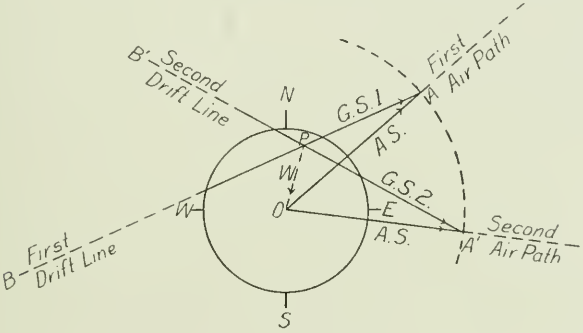
FIG. 11.



desirable to avoid. The Wind-gauge Bearing Plate (Fig. 11) of Major Wimperis enables one to determine the ground speed by either of two methods without departing more than 25° from a given course. The geometry is as follows (Fig. 12):

If AB and $A'B'$ are two traces of the drift on a transparent-bearing plate which is kept properly oriented with respect to the compass points, and if AO and $A'O$ are in the corresponding directions of air speed, and proportional to these speeds, then we know that the wind vector must have one end at O and the other end on both AB and $A'B'$, and hence at their intersection P. PO is therefore in direction and magnitude (on the scale of AO) the wind velocity, and AP and $A'P'$ the two ground speeds. The "wind point" having been located, the ground speed may be at once determined without observation for any course and air speed, so long, of course, as the wind remains constant.

FIG. 12.

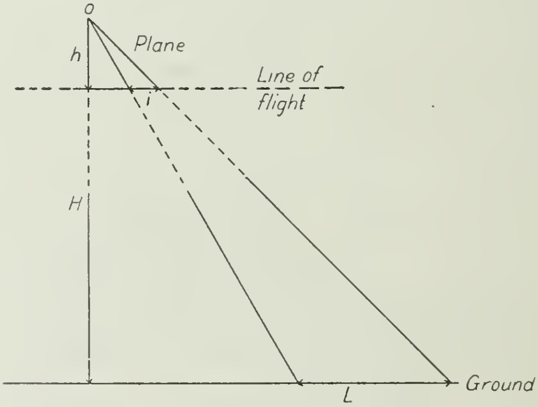


The ground speed may also be determined by timed observations of drift between fixed points on a drift bar, swung so as to be parallel to the line of drift. If h (Fig. 13) is adjusted for altitude so that $h = kH$ then $l = kL$, and k and l may be so chosen that $L = 1$ mile, in which case the ground speed will be 3600 divided by the number of seconds taken for an object to pass along l. In many types of instruments scales are provided which automatically carry out this and similar computations.

Various other schemes have been proposed and tried as ground-speed meters, with the general object of reducing the calculation involved and increasing the accuracy. Some of the most ingenious, which have not yet been made practicable, involve a moving index or tape whose speed can be adjusted until it synchronizes with the apparent ground speed; the device could be graduated to read directly the ground speed since if $h=kH$, then $s=kS$, where s and S are, respectively, the index speed and ground speed. It should be remarked that for ground speed observations over the sea smoke bombs may be dropped to serve as reference points by day, and flares by night.

Navigation by the determination of position, the only method available when flying over clouds, involves either astronomical or radio observations. For the former the primary instrument is the *sextant,* which, for cross-oceanic flights, is likely to be of very considerable importance. Its use was the subject of careful experimentation during the war by Doctor Russell, Captain Webster and Captain Gault at Langley Field. The fact that the horizon is frequently invisible from the upper air, being obscured by haze if not by clouds, makes it necessary to use either some form of stabilized mirror (artificial horizon) or a level or bubble sextant. At Langley Field a damped pendulum stabilizer, and a form of bubble sextant devised by Dr. R. W. Willson, were used, and both are subject to errors due to lateral acceleration. With careful flying the average error of a single observation amounts to only 13′ of arc, but with ordinary piloting it is 26′, while the average error of six observations is only 6′, with careful piloting. While the accuracy of the two instruments was about the same, the bubble sextant proved to be the most convenient. When two heavenly bodies are visible, a location with an average error of

FIG. 13.



seven miles may be made in ten minutes, using the natural horizon, and in twenty minutes with an error of fifteen miles, using the bubble sextant. The British Air Service has developed a different type of bubble sextant, designed so as to permit the observer to look *directly* at the object observed instead of at the horizon, with the idea that in the case of stars at least, such an arrangement will make it easier to find the proper object and point on it.

Directional wireless is of great promise as an aid to aerial navigation, as well as to navigation of the sea, though the very large anomalies and uncertainties, amounting at times to 90° or more, which have been discovered and studied during the past two years at land stations, make it appear very doubtful whether long wave transmission will ever be useful for this purpose. Short and discontinuous waves seem to give indications of direction reliable to perhaps 2°, but the use of short waves will very much limit the range. There is still the possibility, though not the probability, that the anomalies will be found less in magnitude in the air and over the sea. Directional wireless may be used in several ways. For example, the plane may send out a signal, which may be received by several Direction Finding stations. The several bearings of the plane being collected at one station and plotted, the plane's position may be determined and sent back to it by radio. Again, the p'ane may carry a direction-finding set, the bulkiest part of which is the coil three or four feet square, with which the bearings of certain known stations may be taken, and from these the position of the plane may be quickly found graphically. In the case of smaller planes, it is necessary to fix the direction-finding coil with respect to the plane and turn the plane to face successively the various sending stations. In either case the compass, or a special neutral gyrostat with horizontal axis, must be used to give a fixed direction from which bearings may be taken, but either a compass or a gyro will maintain a fixed direction more accurately in a plane which is itself not turning, so that this as well as the greater ease and speed of observing is an argument in favor of the rotating coil whenever its use is possible.

Stabilizing Devices.—The primary purpose of all such devices is to indicate, or to adjust something to, the vertical. Hence the arrangement must be sensitive to gravity—hence no "neutral" gyrostat or "neutral" inertia body will do. A pendulum is the simplest form of vertical indicator—and for some purposes is very useful, especially if provided with internal instead of external damping, as has been done in various forms of gyroscopic pendulums. Doctor Duff's gyro damped pendulum bombsight is an example. An absolutely neutral gyro mounted in gimbals would of course be useless for our purpose, since even if it were initially given the correct vertical position, its tendency to maintain a fixed direction in space would soon throw it off because of the earth's rotation, or the motion of the aeroplane on the earth, or both. We must therefore have a gyroscope mounted so that there is a gravitational or other couple tending to keep the axis vertical. The less this couple, that is, the more nearly neutral the gyro, the more slowly will it respond to lateral accelerations—but also the more slowly will it return to vertical after being disturbed. But even with such a couple, if there were no friction in the gimbal bearings the gyro would not return if disturbed, but would *precess* around the vertical, a real gyroscope being gradually brought into the vertical by friction of the gimbal bearings. Hence various devices called " erectors " have been used to introduce a couple at *right angles* to the plane containing the axis and the vertical, which will restore it to the vertical when disturbed.

All of these involve in effect one or more free short-period pendula, and it is to the average vertical as defined by these that the gyro will tend to be set. As such a pendulum will quickly adjust itself to the " apparent " vertical it will, unless otherwise provided for, at once bring to bear a couple tending to move the gyro into line with the apparent vertical, the " erector " becoming a " disturber." In ordinary use it would be possible to keep the gyro axis at all times within, say, 8° of the *true* vertical, so that it would not be necessary for the erector to act beyond this range. Hence there would be an advantage in arranging to have the erector automatically cease to operate when the " apparent " vertical departed by more than, say, 8° from the true vertical. This may be very simply accomplished with some types of erectors. It would also be convenient to have means whereby either the gyro could be clamped, or the erecting mechanism thrown out of action when the disturbing forces were very large.

Among the erecting mechanisms which have been devised mention should first be made of that of Dr. J. G. Gray, which has achieved very considerable success. The essential feature is a revolving disc having specially curved slots in which roll a number of steel balls, the whole being rigidly attached to the gyro frame, and the disc being slowly rotated by either an electric motor or air turbine. The plane of the disc is ordinarily normal to the direction of gravity, in which condition the balls are symmetrically arranged around the axis of rotation. If the gyro and the disc are displaced out of this symmetrical position the balls roll, and, due to the combined action of the rotation of the disc and the curvature of the slots, the displacement of the balls is such as to give a couple in a plane at right angles to the plane in which the gyro axis has been moved, which tends to erect the gyro. Of course the erector also tends to move the gyro axis out of the true vertical into the apparent vertical. The magnitude of this couple and hence the rapidity with which the disturbed gyro is restored to the vertical may be increased by increasing the speed of the disc. This very ingenious device has been further developed than any other, and shown to be practicable and reliable, but there does not seem to be any easy way to limit the range through which the erector acts.

A second scheme has been worked out by the Sperry Company and Doctor Lucian of the Air Service. This involves two short-period pendula, swinging around the gimbal axes of the gyro in the fore and aft and transverse planes, each carrying a roller contact which plays over a two-part metal contact arc. In the symmetrical position, when apparent gravity is parallel to the gyro axis, neither roller makes contact with either half of its arc, but if the gyro is displaced in either plane a contact is made which actuates an electro-magnet in such a way as to introduce a torque at right angles to the plane of displacement, which tends to erect the gyro.

A third form, which was extended and improved by the Air Service, originated, I think, with one of the early forms of the gyroscopic compass. This again involves two short-period pendula each of which, in the symmetrical position, covers two small air outlets. When displaced, one or the other of these is opened and the reaction of the escaping air-jet is in the plane perpendicular to the displacement and in such a direction as to erect the gyro.

Such gyroscopic devices as we have been describing are of fundamental importance as auxiliaries attached to bomb-sights, cameras, artificial horizons, ground-speed indicators and other apparatus which it is desired to maintain as nearly as possible in a fixed relation to the true vertical. Attached to a double pivot symmetrical compass, they would eliminate the turning errors of that instrument, but at the cost of undue complication; attached to a bomb-sight they would eliminate the largest errors of bomb-dropping, as was about to be practically demonstrated on a large scale just at the close of the war. They also contribute an essential element to the successful application of aerial photography to accurate topographic mapping. It is difficult to state the accuracy with which they will operate, as this depends entirely upon the conditions of use, but it is safe to say that in a carefully piloted plane the best of them would certainly maintain the true vertical to 1° or less.

There remains to be considered only one class of instrument, all of which are still in the stage of a dream rather than a realization, that is, absolute position indicators which would indicate at any time, without any outside observations, the absolute position (latitude and longitude) of a plane. So far as known, experiments and suggestions have been along the following lines:

1. The use of the direction of total magnetic force.

2. The gyroscopic maintenance of a fixed direction, compensated for the earth's rotation.

3. The double integration of acceleration to give velocity and then distance travelled (really automatic dead reckoning).

All of these would involve, among other things, a satisfactory stabilizing device, but the additional difficulties are so great that they have so far proved insurmountable. I feel that this problem of a position indicator is a sufficiently difficult one to leave to the readers of the JOURNAL, and worthy their best efforts.

The High Frequency Spectra of Lead Isotopes. C. D. COOKSEY and D. COOKSEY.—Aronberg, corroborated by Merton, has found a difference of .0043 Angstrom between the wave-lengths of a certain line of ordinary lead and of lead of radioactive origin. Others have investigated the X-ray spectra of lead and have stated that the spectra of ordinary and of isotopic lead differ in wave-length by only a few ten-thousandths of an Angstrom. The authors confine their work to a single line of the L-series and conclude that the two varieties of lead give lines which differ in wave-length by less than .005 per cent.

G. F. S.

INITIATION OF MILITARY EXPLOSIVES.*

BY

WILLIAM A. CORLEY, M.S.
Lieutenant Commander U. S. Navy.

I. INTRODUCTION.

THE first use of an initiator—in other words, of a small amount of some sensitive substance through which explosive action of a less sensitive main charge might be brought about—came in the early part of the nineteenth century. The slow and cumbersome matchlock had given way to the flintlock during the previous century, but, even with this improvement, the time between the decision to fire and actual ejection of the bullet was still considerable, loading was slow and difficult, and the action was by no means certain. In 1805, the Rev. A. J. Forsythe, a Scottish clergyman, proposed to the British military authorities the use of a mixture of potassium chlorate, charcoal, and sulphur as a primer for small arms; a number of experiments were made, but the method was not adopted. Nine years later, several men, of whom J. Shaw of Philadelphia seems to have been the first, independently developed the percussion cap loaded with fulminate of mercury. With this cap, our modern methods of igniting propelling charges came into being; the only essential changes since then have been the introduction of electric firing for certain purposes, and the interposition of auxiliary ignition between the initiator and the main charge to ensure proper initiation of large charges.

The invention of the percussion cap brought about another development, and one which, perhaps, the inventors themselves did not foresee. As early as 1588, an Italian refugee in the employ of the Dutch, had used an explosive shell filled with black powder, employing as a fuse a tube or pipe filled with slow-burning powder which was ignited by the discharge of the gun. Such shells were only of use against material, for men usually had plenty of time to get out of the way before they exploded. Efforts were made to improve timing and to get greater certainty, but this type of fuse was never satisfactory even in the low velocity artillery of that period. The application of the percussion cap to this problem was soon seen; in 1846, Quartermaster Freeburn of the British Army brought out a time fuse in which a percussion member was operated by the shock of discharge of the gun, and four years later Commander Moorson, of the British Navy, invented a fuse firing on impact. In 1853, the Russian fleet made the first use of the percussion fuse, against the Turkish at Sinope; the effect was great.

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* Communicated by Dr. Allerton S. Cushman.

This was only the first step in the development of the modern shell—two further discoveries were necessary to its development. The first of these came in 1864. In 1859, Alfred Nobel, a Swedish engineer, became convinced that nitroglycerine, which had been discovered eight years earlier, was destined to be of great importance to the engineering profession. It was admittedly the most powerful explosive known at the time—perhaps the most powerful that ever would be known. Unfortunately, it could not then be used, for the only practical way of setting off an explosive for use in blasting was by a spark or flame, and nitroglycerine, instead of exploding under such conditions, would usually only burn quietly. After five years of constant research, Nobel found that a small charge of fulminate of mercury, which can be exploded readily by heat or flame, would completely and surely detonate a large charge of nitroglycerine. " The step from the use of fulminate of mercury in caps for the ignition of powder in weapons to its use as a means of converting the igniting flame of safety fuse into the percussive effect necessary for the ignition of the new explosives may at the present time seem to be a small and simple one, but nevertheless, as has been rightfully acknowledged, it is the one which has made possible the commercial use of nitroglycerine and most modern explosives." (Colver, p. 5.)

Nobel's invention was immediately applicable to mines and torpedoes for military use, and in 1868, E. O. Brown, a chemist attached to the British Ordnance Department, demonstrated that fulminate would detonate gun-cotton, which had been discovered in the same year as nitroglycerine, and which was being investigated by the ordnance departments of several nations. It was quite different with shells; here the filler must be sufficiently insensitive to shock to withstand discharge from the gun without exploding. Experiments made with the powerful new explosives had failed on this account; some chemists of the day, indeed, feeling that sensitiveness and power were closely related in the organic explosives, held that an explosive sufficiently inert for use in shells would show no particular advantage over black powder. The possibilities of the trinitrated benzene derivatives had not yet been recognized, although several of them had been prepared, and one, trinitrophenol or picric acid, had been known for a hundred years and had been used extensively as a dye. It was not only that these substances are difficult to explode by any ordinary means; in addition to this, it was then considered that, for good effect, the oxygen content of an explosive system must be sufficient to burn all the carbon present to carbon dioxide, and that an excess of oxygen was desirable. By this reasoning, it appeared that compounds of the picric acid type, which do not contain enough oxygen to burn the carbon present even to the monoxide, would only be of value as a substitute for charcoal in the familiar black powder mixture.

The first hint of the possible use of any of these substances was given by Sprengel, a noted explosives chemist, in a lecture delivered before the chemical society in London in 1873. In the course of this he stated: " It is here noted that picric acid alone contains a sufficient quantity of available oxygen without the addition of any foreign oxygen carrier for it to be an extremely powerful explosive, provided that it is ignited by means of a detonator." The full significance of this statement was not realized, and no further developments were made until 1885, when Eugene Turpin, a Frenchman, announced that, provided the initial impulse was sufficiently violent, pure picric acid was one of the most powerful of explosives, and announced to the world its value as a filler for shell. The design of shell he proposed, in fact, is essentially the one used to-day. After more or less hesitation, for it seemed inconceivable to many authorities that an explosive of such power could be at once reliable in action and safe in the bore of the gun, picric acid was universally adopted as a shell filler (lyddite, melinite, schimose, pertite, etc., are all either pure picric acid or mixtures consisting mainly of this substance). The subsequent replacement of picric acid by other explosives, notably trinitrotoluene, detracts in no way from the importance of Turpin's work; the principal, and often the only components of these explosives are nitrated benzene derivatives like picric acid, and therefore of a class generally neglected before Turpin's discovery.

It will be noted that a differentiation has been made between the initiation of propellants and of high explosives. The two actions are quite different. Propellants are explosives of the first order, which may be exploded by direct action of a flame; the high explosives used are of the second order, and full explosive effect is to be obtained only when they are subjected to an intense initial impulse, such as that given by the detonation of another explosive. Propagation of the explosive impulse through propellants is slow, being never much in excess of one metre a second; the velocity of propagation through a high explosive may exceed 8000 metres per second. For best results with propellants, the initiating effect should be constant—an increase as well as a decrease of the effect is undesirable; the value of high explosives is dependent upon their energy being released in a very brief time, and their effectiveness increases as the time required for the explosive reaction is decreased; it follows that an increase of initial impulse above the standard is never detrimental, and may be advantageous. The initiation of propellants, or ignition, and that of high explosives, or detonation, will therefore, be considered separately.

II. IGNITION AND THE IGNITION SYSTEM.

The requirements of the ignition system are as follows:

(*a*) Certainty of functioning; a single firing impulse must be sufficient to cause ignition;

(*b*) Rapidity of action; many weapons, such as small arms and naval guns fired by gun pointers, can be held on the target only for a brief interval of time;

(*c*) Regularity of ballistics; the charge must be ignited in such a manner as to give the desired muzzle velocity to the projectile, without causing pressures in the gun in excess of those set by the gun designer;

(*d*) Regularity of firing interval; this quality becomes of importance with naval guns fired by director, and aeroplane machine guns firing through the propeller.

Under the conditions actually obtaining, these requirements will be satisfactorily fulfilled if the action of the ignition system is sufficiently uniform. Smokeless powders differ enough from lot to lot to make it necessary to determine the weight of charge for each lot experimentally; this procedure automatically takes up any constant ballistic error due to ignition. Assuming that the system is so designed as to give the required rapidity of action—and the experimental data indicates that this is generally true—the only requirement in practice is that the igniting effect always be the same.

There is little definite quantitative data available upon the effect of changes in ignition. As in all problems connected with interior ballistics, it is difficult to control experimental conditions to a satisfactory degree, to obtain accurate data, and to analyze correctly the results obtained. It is certain, however, that changes in ignition effect exert their influence by changing the rate of combustion of the charge. The rate of combustion of propellants is a direct function of the temperature and pressure, and the changed initial conditions resulting from a change in ignition tend to persist throughout the decomposition; one of the advantages claimed for powders of the cordite type, which contain nitroglycerine as well as nitrocellulose, is that their rate of combustion is less sensitive to changes of pressure than that of the "straight" nitrocellulose colloids, and that, therefore, ballistic results are more uniform.

Ignition less than the standard is far more common than excessive ignition. Its effect is to decrease the rate of combustion of the charge. As a result, the maximum pressure is lower and occurs later, the muzzle pressure is higher, and the muzzle velocity somewhat lower, since more of the energy of the propellant is lost through the muzzle after ejection. Dispersion will be increased somewhat, partly because under conditions of slow combustion the powder itself does not burn with the best regularity, partly because high muzzle pressures of themselves tend to cause erratic flight of shell. With still smaller ignition effect, and a still slower rate of combustion, the projectile will leave the muzzle before all the powder has been burned; a decided drop in muzzle velocity and a considerable increase in dispersion will result. At the same time, excessively high pressures may occur, due to "waves" of pressure (this phenomenon is not uncommon with powders too slow for the gun). Complete failure to fire the main charge may be regarded as the limiting case of insufficient ignition. In addition to its effect upon ballistics, insufficient ignition will at the same time cause increase and irregularity of the firing interval, thus bringing about still further loss of accuracy under service conditions.

The tendency of excessive ignition is to increase maximum pressure, to cause slightly greater muzzle velocity, and to reduce the firing interval. Of these variations from standard, only the first can ever be great enough to be of importance; practically, it is almost impossible for the excess in ignition effect in service to be enough to cause dangerous pressures. Excessive pressures in service, if due to ignition, are apparently quite as likely to be caused by insufficient ignition effect.

Part of the trouble in the ignition system is due to the powder itself. Smokeless powders, and particularly the "straight" nitrocellulose powders, are rather hard to ignite, and burn very slowly at atmospheric pressure. In all except the smallest guns, it is necessary to employ an ignition train of more inflammable explosives, not only to ensure adequate ignition of the propellant, but to build up the pressure somewhat so that the initial rate of combustion may be higher. The action is simple—the initiator, in exploding, ignites the inflammable ignition charge, and this in turn sets off the main charge. Not uncommonly there is an additional step—the first ignition charge, instead of acting directly upon the main charge, sets off a second and larger ignition charge, and this fires the propellant itself; other ignition charges may be distributed through the main charge. The last stage in the ignition train usually consists of black powder; the intermediate stage, where used, may be of finely-divided black powder, or of an even more sensitive and quick-acting substance. The first ignition charge is assembled in the same unit as the initiator, thus forming the "primer"; the final charge in the train, where more than one is used, is usually assembled with the charge. The size and distribution of the ignition train, especially of the final stage, varies considerably with different designers.

The ignition train tends to make for regularity of ignition effect even when the action of the initiator—the member most likely to function badly—is not satisfactory. The substances used in the intermediate stages have a sufficiently high rate of combustion to give about the same effect even when not ignited thoroughly. Poor functioning in other than the final stage, however, tends to lengthen the firing interval somewhat, and does cause a decrease of ignition effect; for instance, a change in the distance between two members of the train may cause a distinct change in ballistics. A defective final stage—such as may be produced by allowing the black powder to get wet—will of course always result in insufficient ignition. It has never been conclusively proved that variations in size of standard ignition charges (provided, of course, they are not made too small) or in distribution, make any considerable difference in regularity; the constant change in ballistics which results is, of course, taken up in fixing the charge at the proving ground.

In small arms, the initiator is required to ignite the propellant directly; with this system, ignition irregularities are far more common than in larger guns. It is commonly believed, in fact, that the primer (or initiator) has more effect upon the ballistics of small arms than any other factor. In the first place, the margin of operation is much smaller—an initiator which can set off the inflammable explosives used in the ignition train may entirely fail to ignite smokeless powder. Again, the substances used for initiators, as will be seen later, are from their very nature especially liable to deterioration in storage, with consequent change in ignition effect. Not infrequently the charge does not fill the cartridge case completely and the distribution of the charge around the primer differs from round to round, with a corresponding change in the ignition effect of the initiator; this is the foundation for the belief that a rifle or pistol shoots more accurately if pointed vertically first and then brought down on the target. Finally, the tendency toward regularity of action found in the ignition train is absent here; variations in action of the primer will inevitably result in corresponding variations in ignition effect. The space available is too small to permit use of a train; the problem, therefore, resolves itself into a question of obtaining an initiator which will have an adequate margin of effective operation, will be constant in its action, and will retain these qualities under the various conditions encountered in storage and in service.

III. DETONATION.

In order to obtain full explosive effect from explosives of the second order—the class which includes all military high explosives—it is necessary to use a small charge of an explosive of the first order. The high explosives in use, as has already been pointed out, can be employed in shell only because they are insensitive to shock or impact; when ignited, they usually burn, if at all, rather slowly and quietly, and detonation, if produced, is rarely complete. To insure rapid and complete release of the potential energy of these substances, a strong initial impulse such as that obtained from another explosive is required. There is, in fact, a close connection between initial impulse and effectiveness. "The character and intensity of the initial impulse influence the course of an explosive reaction to such a large extent that it has been said, and not without justification, that the effectiveness of an explosion depends more upon the initial impulse than upon the explosive itself." (Brunswig, p. 31.)

The manner in which the explosion of one substance brings about the explosive decomposition of another has been the subject of experiment and discussion ever since Nobel announced his discovery that fulminate of mercury was an efficient detonating agent for nitroglycerine. The explosive impulse is not transmitted from one charge to the other by the direct transfer of heat, nor does it seem to depend upon the propulsion of particles of the primary explosive against the secondary charge; detonation still occurs when a film of water, glass, or metal is interposed between the two charges, although a distinct loss of explosive impulse results from such interpositions; it has been found, indeed, that the substitution of a film of water for an air-gap has resulted in an increase of initiating effect.

Abel brought forward, in 1869, the view that the action was due to synchronism of molecular vibrations; he had found that 6.5 grams of nitrogen iodide is insufficient to detonate nitroglycerine or gun-cotton, and that 3.25 grams of nitrogen chloride was required, while 0.3 grams of fulminate of mercury, which is less powerful and has a lower velocity of detonation, was always enough to produce satisfactory action. This hypothesis has never been accepted. According to it, each explosive should show such perfect synchronism with itself that it would furnish the best detonator for itself (Victor Meyer). Gun-cotton exploded over nitroglycerine will cause detonation of the latter, but the converse holds only when the charge of nitroglycerine is large; if wave synchronization is assumed, the action must be completely reciprocal (Berthelot). If the various explosives be arranged in the order of sensitiveness, as determined by the minimum quantity of a given detonator agent required to detonate completely a fixed weight, the order will be different with different detonating agents (Brunswig). Some authorities feel, however, that the wave-synchronism theory should not be totally disregarded; for instance, the detonation of a cast or pressed charge of the trinitrated benzene derivatives, such as picric acid, is accomplished best through a "booster" charge of material of the same class as the charge. (Colver, p. 595.) The efficiency of the nitro-aromatic explosives as boosters, as compared to nitroglycerine, for instance, has not yet been explained in a satisfactory manner.

The explosive-wave theory of Berthelot, is the one generally accepted to-day. According to his idea, the transmission of the explosive impulse differs in no way from the propagation of the impulse through a charge; transmission and propagation both take place through the agency of an explosive wave, which also has the power of propagating itself, and therefore of bringing about explosion, through intervening mediums. The wave is considered as a recurring cycle of released and transformed energy, having four phases:

1. *Transformation of Mechanical Energy to Calorific Energy.*—A part of the mechanical energy set free in one layer of the explosive is converted instantly into heat energy in the adjacent layer by reason of the impact of molecules. Since the movement of the molecules is radial, the efficiency of this conversion is dependent upon the shape of the charge and the location of the detonator within it; for a long thin column of explosive detonated at one end, the efficiency will be less than 50 per cent., since the molecules are confined by the explosive only on one side; if, on the contrary, the action is taking place in the interior of a mass of explosive, the efficiency will be practically 100 per cent. The mechanical energy that is not converted into heat energy exerts pressure on the confining medium and thus becomes the vehicle through which work is accomplished. The thickness of the layer of the explosive which enters into this

phase is not only dependent upon the amount of energy available, but varies with the physical properties of the explosive material, principally with its elasticity. The less elastic the explosive material, the thinner the layer, and hence the more times the cycle will recur in a unit length of the explosive material. This phase, to put it briefly, subjects the layer to sudden heating under great pressure.

2. *Transformation of Calorific Energy to Chemical Energy.*—Some of the calorific energy of the layer is used to overcome the chemical stability of the explosive material, and thus to release the potential energy of the layer; the rest is used to accelerate and reinforce the chemical action.

3. *Transformation of Chemical Energy to Calorific Energy.*—Once the chemical stability of the material is overcome, its potential energy is converted into kinetic energy—largely calorific energy; all military explosives develop heat on detonation. This phase differs from the others in that it supplies kinetic energy to the cycle, while each of the others consists only of a transformation of the kinetic energy obtained from the preceding phase, and therefore can have no more kinetic energy than the preceding phase is capable of transferring.

4. *Transformation of Calorific Energy to Mechanical Energy.*—The large volume of gases formed from the layer of explosives is in an extremely active state of molecular vibration, and these molecules are therefore manifesting their energy as kinetic energy. (Bulletin 59, p. 9.)

The full action of a simple explosive system, according to this theory, is essentially as follows: sufficient heat energy to overcome the chemical stability of part of the detonator is supplied from outside the system, either by direct action of a flame or incandescent solid, or by the conversion of the kinetic energy of a blow into heat; the explosive wave is set up by the resulting decomposition of part of the detonator and passes rapidly from layer to layer until all the potential energy of the detonator has been set free, mostly in the form of mechanical energy; this mechanical energy the explosive wave transmits to the main charge, where it initiates the decomposition of the first layer and propagates itself through the explosive as already described.

This theory explains the intimate relationship between initial impulse and explosive effect If a large amount of the second order explosive is suddenly decomposed by the direct action of the detonator, the amount of explosive decomposed in the second cycle will be large, a large excess of energy will be available for accelerating decomposition in the second phase of the second cycle, and the time necessary for both cycles will be short, thus reducing the loss of energy by radiation and conduction to a negligible quantity. (The action is so rapid in case of detonation that the decomposition proceeds nearly adiabatically.) Since additional energy is furnished to the explosive wave in each of these cycles in excess of the amount lost as a mechanical energy, the velocity of propagation will increase to the value at which dynamic equilibrium obtains—in other words, to a maximum dependent upon a number of conditions such as the chemical and physical characteristics of the charge. Where only a small amount of explosive is decomposed by the detonator, or where the initial decomposition is slow, as by the action of a flame upon a second order substance, the radiation and conduction losses become significant, the first cycle furnishes little or no excess energy to accelerate decomposition in the second, and the decomposition proceeds as a simple combustion; in some explosives and under some conditions the reaction will die out entirely. It may not be going too far to say that explosives of the second order lack the ability to accelerate burning to the detonation stage, and the detonator supplies the required acceleration. (Tech. Paper No. 162, p. 22.)

The tendency of propagation to proceed at one of two definite velocities is well recognized. " Under conditions usually in force only one or the other limiting value of velocity of propagation obtains in explosive processes, and the corresponding phenomena are accordingly characterized either as deflagration, where the velocity of propagation is only a few metres, or as detonation, where the velocity reaches almost as many kilometres per second." Where escape of energy is prevented, as when the container is very strong, a deflagration can end with a detonation; similarly, where there are hindrances to the propagation of a detonation, such as large gaps in a column of explosive, a detonation may degenerate into a deflagration (Brunswig, p. 80). These phenomena are to be expected in light of Berthelot's theory.

The effectiveness of the explosion, it has already been stated, is largely dependent upon the rapidity with which the energy is set free—in other words, upon the velocity of propagation. The total energy set free by a low order explosion[1] may be the same as that of a detonation, but the brisance, or shattering effect, is far greater in the latter case; the rate of increase of pressure and the maximum pressure produced are also greater, not only in contact with the charge, but at points removed from it—a matter of considerable importance in constructions in which the radius of effectiveness is of prime importance, such as depth charges. A secondary effect in low-velocity explosions is the driving out of a portion of the charge before the explosive impulse can reach it, with a consequent direct loss of energy. Under certain conditions, to be sure, the finely-divided powder which results will be of some value through its choking effect upon personnel; it is not, however, particularly toxic, and in confined spaces is not even as effective as the carbon monoxide produced by decomposition. (Colver, p. 591; after Lewin and Poggenburg.)

The course the reaction takes, as well as its velocity, may be dependent upon the initial impulse. For instance, of the various ways ammonium nitrate may be decomposed, three are explosive. If subjected to the impulse of a strong detonator, it yields nitrogen, water vapor, and oxygen; a weaker detonator causes decomposition into nitrogen, nitric oxide and water vapor; finally, gradual heating without material increase in pressure results in the formation of nitrous oxide and water vapor, no nitrogen being set free. (Brunswig, p. 32.) The table below (Brunswig, Table 6) gives the heat of explosion, the volume of gas, and the product of these two values—a quantity which Berthelot has proposed as a characteristic expressing the maximum work performed by the explosion.

Table I.

Decomposition of Ammonium Nitrate.

Impulse	Heat of Explosion Calories	Gas Volume Liters	Berthelot Characteristic
Strong detonator	421	976	411,000
Weak detonator	140	976	137,000
Gradual heating	151	836	126,000

Even if Berthelot's theory of the mechanism of transmission is accepted, the influence which the chemical and physical characteristics of the detonator exert upon the effectiveness of the initial impulse still remains to be explained. A small amount of fulminate of mercury, for instance, will effect the detonation of a large charge of an explosive of the second order, although many other explosives apparently more powerful in every way will accomplish the same result, if at all, only when used in large quantities. It would be expected that efficiency as a detonating agent would depend upon the rapidity of explosive decomposition primarily, and upon the energy content to a somewhat less degree, but there is apparently evidence that this does not hold. The velocity of propagation in nitroglycerine has been determined to be over 7000 metres per second, as against less than 4000 metres for fulminate of mercury, and its potential energy is four times that of fulminate, yet it has not the property of initiating detonation in other explosives unless used in large quantities; it has already been pointed out that nitroglycerine is not effective as a detonating agent for guncotton. Abel's demonstration of the detonating efficiency of fulminate of mercury as compared with the highly brisant nitrogen halides has also been referred to. The presence of a heavy metal was for a time thought to be necessary, because the high specific gravity of such compounds allowed high density of loading and correspondingly high maximum pressures, and possibly because the very heavy vapors of the metal had a special value in detonating the secondary charge; organic compounds are now known which are more effective, weight for weight, than any of the metal compounds. (Tech. Paper 162, p. 18.) The particular property or combination of properties which determine the efficiency of a substance as a detonating agent have not yet been successfully determined or measured.

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[1] "Low order explosion" is frequently used instead of "deflagration"; similarly, "high order explosion" is synonymous with "detonation."

Storm and Cope believe that the initial rate of detonation is the most important property of detonating agents. In view of the difficulty of determining accurately the rate of detonation of detonating compositions, they made a comparison of the relative rates of four such substances by observing the minimum weight of each which would be sure to shatter completely a small open glass test tube in which it was placed, when exploded by rapid heating. The results were as follows:

Mercury fulminate	0.07 gram
Fulminate, 90 per cent.; potassium chlorate, 10 per cent	0.06 gram
Fulminate, 80 per cent.; potassium chlorate, 20 per cent	0.05 gram
Lead azide	0.01 gram

Even 0.001 gram of lead azide in every trial blew the bottom out of the test tube. The quantities of the various compositions required correspond with the minimum quantities of these substances necessary to detonate a given weight of an explosive of the second order, indicating a relationship between shattering effect and efficiency as a detonating agent. Storm and Cope believe that, since the particular property of explosives upon which shattering effect depends is apparently the initial rate of detonation, this property must be one of the factors of greatest importance. They further consider it likely that the usual method of measuring rate of detonation, using a column of explosive of considerable length, gives a value of initial rate for these substances much smaller than the true one. (Tech. Paper 125, p. 39.) In other words, the rapidity with which fulminate of mercury decomposes at the beginning of the action is greater instead of less than that of nitroglycerine, for instance, and for this reason it is a better detonating agent than nitroglycerine. The greater efficiency to be obtained by increasing the rapidity of explosion of fulminate of mercury itself has been shown by Wöhler. He found that the finely-divided fulminate obtained by precipitating it with an acid from a potassium cyanide solution at 0° C. was about three times as effective as the coarser original fulminate, as a result of the faster decomposition of the finely-divided material. (Marshall, p. 513.) Taylor and Cope, following a suggestion of Wöhler, reported that the action of fulminate of mercury was considerably strengthened by superimposing a small charge of a quicker-acting explosive. Lead azide and silver acetylide, although the latter is not of itself a good detonator, reduced by one-half the amount of fulminate necessary to fire a given weight of trinitrotoluene.

Accepting the idea of Storm and Cope that the initial rate of detonation is much greater than the value determined by the methods in use, Wöhler's theory may be taken as a basis for further discussion of the matter. He believes that detonation of second-order explosives is initiated by a sudden and enormous local pressure. Any substance, mixture of substances, or combination of substances that, when placed in the detonator shell and ignited, detonates with such velocity that the walls of the shell do not yield until the entire gaseous product has accumulated so that it can escape all at once and deliver by its kinetic energy a colossal blow, will be an efficient detonator. (Tech. Paper 162, p. 7.) The action is thus dependent primarily upon the rapidity of decomposition, and to a somewhat less degree upon the volume of gas produced (as determined by the composition itself and the density of loading) and to the heat of the explosion.

The views of Taylor and Cope are in general accord with those of Wöhler. In their opinion, the effectiveness of a detonator in practice depends upon explosive energy that may be separated into an intensity factor and a capacity factor. The intensity factor may be called "quickness" and depends upon acceleration of the explosive decomposition. The capacity factor is "strength," and is measured by the total energy of the primer. Of the two factors "quickness" is the more important. According to this idea, greater effectiveness should be obtained by keeping one factor constant and increasing the other, but, if a substance is deficient in one factor, increase of the other should not be particularly effective. This is actually the case. Storm and Cope found that the amount of sand pulverized by a given weight of fulminate of mercury, compared to that pulverized by the same weight of mixtures of fulminate with 10 per cent. and 20 per cent. of potassium chlorate, is a measure of the efficiency of the respective mixtures. (Tech. Paper 125.) Taylor and Cope established the fact that this sand test is a measure of "strength," and that the effect is, therefore, that of varying the "strength," keeping the "quickness" practically constant. The increased effectiveness of mercury fulminate, brought about by a small quantity of lead azide or silver acetylide, illustrates the case of increasing the "quickness" only. Finally, lead azide could not accelerate silver acetylide (which has the necessary "quickness," but not the "strength") sufficiently to improve its action. (Tech. Paper 162, p. 22.)

Tests of the comparative efficiency of detonating agents, such as those referred to above, are made by determining the minimum weight of the agent which will produce detonation of a given weight of some explosive of the second order, conditions such as density of loading, granulation, and the like being kept constant. The explosive effect obtained from the second order explosive, when detonation is secured, is always practically the same, regardless of the amount of the initial impulse or the agent used. Storm and Cope found, in fact, that the total strength shown by four nitrocompounds (trinitrotoluene, tetranitromethylaniline or tetryl, tetranitroaniline, and picric acid) was nearly the same when equal weights of the same priming composition (0.4 gram) were used and the charges subjected to similar pressures. (Tech. Paper 125, p. 59.) The dividing line between complete and partial detonation is sharp; it is possible to determine within 0.01 gram (around 5 per cent.), the weight of a detonating agent necessary to detonate completely 0.4 gram of TNT (trinitrotoluene) or tetryl, although strong detonations sometimes occur with charges several hundredths of a gram less than the minimum charge certain to produce detonation. (Tech. Paper 162, p. 12.)

IV. THE DETONATING SYSTEM.

The detonating system in military explosive constructions is still not at all satisfactory in its action. One man in close touch with munitions manufacture during the World War has estimated that 50 per cent. of the shells made for the various belligerents were "duds," because of mechanical faults or defects of the detonating system proper; this includes the large number which were rejected on inspection and never reached the front, but does not include those which would function, but with less than maximum effectiveness. Where the detonating system was responsible, the fault frequently lay in the explosive substances, which deteriorated with time and thus became less sensitive or effective; in a great many cases the design was unsatisfactory, and failed to provide an adequate margin between operation on the one hand and partial or complete failure on the other.

An underlying cause of many of these failures is the paramount necessity for provisions against premature explosions; one premature explosion may be more serious in its results than a rather large percentage of failures. The mining squadron which laid the North Sea barrage carried over 1,500,000 pounds of trinitrotoluene on each excursion, the larger mine-layers carrying 250,000 pounds each—the accidental explosion of a single mine might have wiped out the entire force and defeated the project. As they went in and out of the base, indeed, they passed the wreck of a British mine-layer which had been blown up in just this way; among those killed were several of the British officers most experienced in mining, the loss of whose services was more serious than the loss of the ship.

Safety precautions of two kinds are usually taken; in the first place every effort, both in design and in handling, is taken to prevent accidental explosion of any member of the system; besides this, provisions are made in the design so that if premature explosion of the detonator, which is very sensitive and far more liable to be fired accidentally than the booster or the main charge, will not cause explosion of the main charge. The first kind of precaution rarely affects the design of the detonating system directly, except in so far as reduction in the size of the detonator tends to reduce the danger of an explosion. The second precaution consists essentially in the introduction of a gap or break in the detonating system between the detonator and the booster (or main charge, when no booster is used), the gap being eliminated automatically when the assembly is launched, shot from a gun, or dropped, as the case may be; the detonator must not be so large that it may transmit the explosion across the gap. In mines, torpedoes, and bombs the detonator is very often not inserted until immediately before use, and then is put in the firing position; in this case there is no limit to the size of the detonator, but there is increased danger of premature explosion of the charge after the detonator is inserted, and the necessity for quick and easy insertion may complicate the mechanical design.

The arrangement of different detonating systems differs greatly with the purpose of the construction in which they are used, the particular conditions of use for which the safety precautions must provide, the size and shape of the space available, and a number of other variables. The general action is, however, the same in all cases: the initiator, a first-order explosive, is exploded by the firing impulse; this explosion ignites the detonator charge, composed of a detonating agent, which converts the ignition into a detonation; this detonation may be used as the initial impulse for the main charge, but almost invariably acts through a booster, which, like the main charge, is an explosive of the second order.

The use of an initiator to ignite the detonator charge has no bearing on the effectiveness of the explosion, but is, nevertheless, of distinct practical advantage. It need not necessarily be a detonating agent; it is possible, therefore, to use substances which are less likely to deteriorate, or are more sensitive to the firing impulse, or which have some other advantage over the detonating agent employed in the charge. In percussion firing, the initiator must be small, for increase above a given size for a fixed value of impact causes a notable proportion of misfires. In delayed action and time fuses, where a slow-burning powder train is used to cause a certain time to elapse between the firing impulse and detonation, an initiator separate from the detonator charge is obviously necessary. In very small charges, however, the initiator may be eliminated, and the detonator receive the firing impulse directly; in such cases the booster is also omitted. The initiator and the detonator charge are always assembled in the same unit—in shell they are contained in the fuse, and in torpedoes, mines, and bombs they are placed in a single container to form the " detonator."

The principal reason for use of a booster is to reduce the amount of detonating agent required, and thus to decrease the danger of a premature explosion. High densities of loading, with a consequent decrease in sensitiveness, are habitually used in main charges in order to obtain the maximum explosive effect. Instead of increasing the power of the detonator sufficiently to overcome this decrease in sensitiveness, the detonator is made to act through a booster of somewhat greater sensitiveness than the main charge. The manner in which the booster acts can best be understood by taking a case where the same nitro-aromatic explosive is used in both booster and main charge. Assuming that the detonator gives an impulse slightly less than that required to detonate the main charge, no advantage will result from using a booster of the same density of loading; as the density of loading is decreased, the thickness of the layer decomposed increases, rapidly at first, but more slowly as the distance of the farther side of the layer approaches the rather small maximum distance at which the impulse is able to effect any decomposition; the amount of explosive in unit thickness of layer decreases directly with the density of loading; there is, then, a given density at which the amount of explosive decomposed by the impulse is a maximum. The velocity of propagation through the booster charge, and therefore its effectiveness, also decreases with decreased density; the most effective density for the booster, therefore, is somewhat above that at which the initial impulse causes directly decomposition of the largest amount of the booster. This value for new substances is at present determined by "cut-and-try" methods; it appears to be dependent upon the state of division of the explosive, and perhaps other factors, as well as upon the booster material itself.

The nitro-aromatic explosives are the only substances now used for boosters; in former years, when guncotton was the only high explosive used for military purposes, it was customary to add a large proportion of water to the main charge to decrease its sensitiveness, and to use a booster (or "primer," as it was then called) of dry guncotton to ensure detonation; now nitro-aromatic explosives are used even here. Tetryl and TNT are the ones most often used, tetryl being generally preferred. It is easier to detonate than TNT, although far from being dangerously sensitive, and is more powerful; a distinct advantage is that moisture in a fulminate of mercury detonator, a small amount of which will prevent its detonating TNT, has considerably less effect upon its effectiveness with tetryl. Tetryl, on the other hand, is considerably more expensive than TNT, and is less stable, especially when not carefully purified. Several other explosives of this class, picric acid in particular, also find an extensive use in boosters. Whatever the substance employed, it is used in a finely-divided state, thereby still further increasing its sensitiveness to the explosive impulse without making it more sensitive to shock. The booster material is always of a high degree of purity in order to obtain the best possible power, stability, and uniformity.

No increase in explosive effect seems to result from the use of a booster, except perhaps for the slight improvement obtained by better distribution of the explosive impulse through the main charge. The results will be practically the same if the detonator is increased to a suitable size and made to act directly upon the main charge; in blasting work, in fact, where the size of the detonator is not limited by considerations of safety, boosters are rarely used. The booster in shell is often assembled in one with the fuse; in mines, torpedoes, and bombs the booster is a separate unit.

No general rules for the size of detonator or of booster necessary to accomplish detonation can be given. The weight of the primary charge (the one which furnishes the impulse) for best results is dependent not only upon the chemical and physical characteristics of both explosives, but also upon many other factors, including the shape of both charges, their location with reference to each other, the design of containers, and especially the distance between the two charges and the medium filling the gap. It is a question whether increase in size of the primary charge above that just sufficient to produce detonation has any influence upon the effectiveness of the explosion. Waddell believes that increase of impulse above the minimum does result in a certain degree of increased effectiveness, even when the secondary charge is of a more powerful explosive than the primary—in other words, that it requires an impulse somewhat larger than that just able to produce detonation to bring out the full power of a second order explosive (private communication); the difference is far smaller, of course, than that between a high order and a low order explosion. Everything considered, the chief point to be considered in determining the size of the detonator and the booster, as far as explosion of the main charge is concerned, is to make them both powerful enough to provide the excess of energy necessary to make the action certain. It may not be amiss to point out, in this regard, that while great power on the part of the detonator will tend to make up for a weak booster, no booster, however large or powerful, can function when the detonator is too weak.

The detonator, in particular, since its power is limited, must be so located that the largest possible proportion of its explosive energy will act upon the material of the booster. The explosive wave, if unhindered, proceeds radially from the exploding substance, and only that portion of it which impinges upon the secondary charge is useful in transmitting the explosive impulse. This point is of importance with boosters only as far as questions of space, assembly, and cost limit the size. Confinement of the explosive wave so that, to escape, it must all traverse some part of the secondary explosive increases the efficiency with which the energy of the primary charge is used; in the long cylindrical detonators which are in common use, the confinement exercised by the shell results in a large proportion of the impulse radiating out from a point at or near the end opposite the initiator; by burying this end of the detonator in the booster material most of the energy of the detonator will be forced to act on the booster.

The location of the detonator and booster, it may be said in passing, exerts some influence upon the effectiveness of the explosion. The speed of decomposition will obviously be best when the impulse upon the main charge acts as if it were proceeding from the centre of gravity of the charge. The distribution of the explosive effect of the charge in different directions is also dependent upon the part decomposed by the initial impulse as well as on the shape of the charge itself, on the design of the container, and probably on other factors; other things being equal, the tendency seems to be for the effect to be at a maximum on the side farthest from the impulse, but no complete study of the matter has as yet been made. The distribution of the primary charge also may be of importance; for example, in a long, slender charge of an explosive of which the rate of detonation is less than that of the booster material, the speed of explosion may be built up practically to that of the booster by having the latter extend the full length of the charge; at the same time, if this explosive be so insensitive that the detonation tends to drop to a deflagration within a short distance, the long booster will improve certainty of action.

A distinct loss of effectiveness of the explosive impulse results from air-gaps between the different charges of the explosive system—the loss is so great that a small air-gap (of an inch or less) between the detonator and the booster is an excellent means of preventing transmission of an accidental explosion of the detonator to the booster. Where a gap exists when the system is in the "armed" or firing position, a considerable increase in the size of the primary charge is necessary, for the radius of effectiveness varies only as the square root of the primary charge, if not even more slowly. As a result of limitations in design, or of poor functioning of the arming mechanism, air-gaps are sometimes found between the detonator and the booster. Air-gaps between the booster and the main charge may result from shrinkage of a cast charge leaving cavities around the booster, or, in shell where the booster does not extend down into the charge, from the charge moving bodily away from the booster on firing, when a nose fuse is used, or on impact in the case of a base fuse. The cavitation difficulty may be eliminated by care in casting; shifting of the charge is to be prevented by use of a sufficiently high density of loading. The detonator and booster cases also reduce the effectiveness of the impulse, but to a much less degree, for denser substances are better mediums for transmission of the effect; the specific ability of a medium to transmit the impulse is probably a function of the velocity of sound through it.

Two or more complete detonating systems are sometimes installed, both being fired simultaneously. This method results not only in greater certainty of action, but, particularly in long charges when a system is placed at either end, in more rapid decomposition, and greater explosive effect. Extra detonators are occasionally distributed through long charges, with the idea of increasing explosive effect and of ensuring complete detonation; these detonators take their firing impulse from the main charge. The advantages obtained are probably not great. (For tests in blasting explosives, see Bulletin 59, p. 68.) Two boosters in series are sometimes used, but usually only for convenience in assembly, to avoid the use of a single booster of a shape awkward to handle or for which the case would be expensive, or for some similar reason. As might be expected, no advantage in explosive effect results from dividing the booster charge into two parts.

The fact that a very slight decrease in the effectiveness of a detonating system just capable of always producing a detonation will result in a system which is never able to bring about anything more than a deflagration, is a point of considerable practical importance in view of our present inability to measure the properties upon which effectiveness of the explosive impulse depends. A newly-designed detonating system may operate in an entirely satisfactory manner in tests, and yet the margin of positive operation may be so small that a large percentage of partial or even complete failures will occur in service. In one case during the World War, a new design which had given detonation on every firing test preliminary to adoption, and which gave every promise of good results in service, failed badly; it was only by making the action of the detonating system more positive that it could be used at all. In another, the inventor of a new construction, finding that the detonator used was wholly incapable of detonating trinitrotoluene across the air-gap which separated them in his design, substituted tetryl for trinitrotoluene and obtained detonation; this he considered satisfactory, although it is obvious that the surplus of power available for taking care of the variations sure to come up in service was not large, and may have been very small.

One of the best ways at present available for determining the operating margin is by lowering the efficiency of the detonating system until the minimum impulse which will produce detonation is found, or until the margin has been proved to be sufficient. This is done better by changes in the explosive materials used than by decreasing the weight of the detonating charge and the booster, for the latter inevitably involves alterations of distribution, of size of air-gaps, of densities of loading, and other important conditions. For instance, suppose the system as designed has a detonator charge of an 80/20 mercury fulminate-potassium chlorate mixture, and a tetryl booster. The effectiveness of the detonator can be reduced by substituting the same weight of "straight" fulminate of mercury for the fulminate-chlorate mixture; similarly, the sensitiveness and the power of the booster can be lowered by the use of TNT instead of tetryl. The detonating system described should, in the opinion of the author, operate satisfactorily under these conditions if it has a satisfactory excess of effectiveness over that barely necessary. If it is desirable to carry the test still further, there can be mixed with the fulminate other substances—oxides of the heavy metals which reduce only to lower oxides and not to the metals themselves, for example—which reduce but do not prevent effectiveness. (See Tech. Paper 162, pp. 13 and 14, for the effect of certain substances upon the efficiency of fulminate of mercury.) At the same time, the sensitiveness and effectiveness of the booster can be lowered still further by mixing with the TNT some such explosive as dinitrotoluene or dinitrobenzene. Whether this or any other test is used, the effectiveness of the detonator in its action upon the booster as well as the effectiveness of the entire system should be determined, as malfunctioning between the detonator and the booster is perhaps the commonest fault in the system.

Direct tests of detonators can be made by the sand test described by Storm and Cope. (Tech. Paper 125; description also appears in Colver, p. 554. For comments, see Tech. Paper 162, pp. 19–21 and p. 23.) It appears possible to develop this method to take care of the entire detonating system, although it is a measure of strength rather than of detonating ability, and therefore not adapted to give direct comparisons of substances differing widely from each other. The sand test will also be of some value in connection with the method described in the previous paragraph, for obtaining comparisons between the materials specified and those used in the tests.

V. INITIATING COMPOSITIONS.

The value of a primary ignition agent, it is seen from the foregoing, depends upon its ability to develop the heat necessary to ignite another explosive; similarly, the value of a primary detonating agent is dependent upon its exploding in the particular manner which will result in the detonation of a secondary charge; in either case, the agent must be sensitive enough to be exploded by a rather weak initial impulse, given by the direct application of heat or by a blow, but must not be so sensitive as to be liable to accidental explosion in necessary handling or in use. From the practical standpoint, the ability to retain these qualities unchanged is equally essential; what we are interested in is the sensitiveness and effectiveness when the composition is used, not what they were when it was first prepared.

It is obvious from the use of these substances that they are particularly liable to deterioration. They are valuable for the purpose of initiation because they are unstable; in other words, the atoms composing the system will rearrange themselves to form other compounds upon slight provocation. In an explosion, this rearrangement takes place with great rapidity and with the evolution of heat and of gases in large quantities; under conditions often prevailing in storage and in service, however, it may take place slowly and give out much less heat, and the products of the reaction may all be solids or liquids. A rearrangement of the latter kind may involve only a single substance, its molecules passing over into a new compound having the same percentage composition as the old, but a different configuration and therefore different properties, or it may result from the interaction of the different substances of the composition with each other or with the container or its coating if it has been painted or varnished; whatever takes place, the new substances formed may react on those still unaltered. Temperature has a decided influence upon the rate with which the action progresses; most reactions are doubled in velocity by a rise of about 10° C. in temperature; compositions which are satisfactory for use in a cold climate may, therefore, prove useless in the tropics. Deterioration, it must be understood, is not a fault peculiar to the initiating agents—the explosives of the second order, which are very stable in comparison with these sensitive substances, very often show changed sensitiveness and effectiveness after being stored for some years. The usual course of deterioration is toward decreased sensitiveness and effectiveness, although products more sensitive than the original composition sometimes result; in any case, heat is evolved, and, unless it is carried away, may increase the temperature above the ignition point of the system.

A condition contributing directly to deterioration, and at the same time directly causing decreased sensitiveness and effectiveness, is the presence of moisture in the initiator composition. If the system could be made and kept absolutely dry, it would for the most part retain its properties indefinitely. Efforts are made to exclude moisture, but a certain amount (often quite sufficient to start deterioration) is always taken up from the air between removal from the driers and final sealing; it is impossible, too, to make the sealing air-tight in every case, and, where leaks occur, moisture is drawn from the air until equilibrium is established. The effect of moisture on the explosive qualities, and the chemical behavior of the constituents in the presence of small amounts of moisture must be given great weight in the choice of initiating compositions.

The size of the particles which compose the initiating agent has considerable bearing upon sensitiveness and rapidity of explosion. In the case of compounds which are in themselves detonating agents, such as fulminate of mercury, it has been repeatedly demonstrated that sensitiveness to impact increases with size of crystals, although the ignition point remains the same. The opposite is true where the system is a mixture of substances which alone are fairly stable; in this case the more intimate mixture resulting from finer division tends toward increased sensitiveness. The time required for the explosive reaction is always less with the finer material, because of the increased surface; the increased effect obtained from very finely divided fulminate of mercury by Wöhler can only be ascribed to more rapid action; it has also been found that the time taken by small-arms initiators to act was much more regular when the sizes of the components were more closely controlled than is ordinarily thought necessary.

The greater exposed surface resulting from decreased size of particles permits deterioration to proceed more rapidly, and increases the amount of moisture which a given weight of composition can absorb. The volume occupied by a given weight of initiation charge under a given pressure is greater with small particles,[2] thus making necessary an alteration of either weight, loading density, or volume, sometimes at the expense of efficiency. The explosion of a very finely-divided composition may be altogether too rapid and violent for good results, and it is impossible to maintain any control of the exposed surface when the ingredients pass the 200-mesh sieve, the finest which can be practically used. (The total surface of a given weight of a substance consisting wholly of particles of the same size and shape increases in inverse ratio to any given linear dimensions, as length of the particles. See "Air-Elutriation of Fine Powders," by A. S. Cushman and Prevost Hubbard, *Journal of the American Chemical Society*, April, 1907, p. 594.) Finally, it is unsafe to grind many of the compounds used, and it is a matter of considerable difficulty and increased expense to make them separate out of solution in a state of very fine division. Everything considered, the size usually taken is the smallest practically obtainable under good manufacturing conditions without the use of expensive additional operations.

Sensitiveness and rapidity of explosion are also dependent upon density of loading. The sensitiveness of practically all compositions, whether single compounds or mixtures, decreases continually with increased density, until in some cases the sub-

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[2] This phenomenon is not generally recognized. The writer, following Cushman, has found the volume occupied by 10 grams of sand, sieved out of the same lot, and settled by tapping on the table, to be as follows (volumes accurate to 0.3 c.c. only):

Mesh	Volume
60–80	6.2
80–100	7.5
100–200	8.0
Past 200	8.5

Cushman has found it impossible to reduce the volume of the finely divided material to that of the coarser even with high pressures. For discussion, see A. S. Cushman, "On the Cause of the Cementing Value of Rock Powders," *Journal of the American Chemical Society*, May, 1903, p. 459.

stance is "dead-pressed" and will not explode at all; the sensitiveness of lead azide, to flame at least, seems to be practically independent of the density. The effect of density upon the velocity at which the explosion proceeds depends upon the composition itself; if it consists wholly or in large measure of a compound explosive in itself, the velocity usually increases with increased density; in the case of mixtures of substances not in themselves sensitive explosives, it increases to a maximum and then drops off. Reliable quantitative data upon this effect is not available because of the difficulty of measuring the velocity of propagation through these substances, but this is in accordance both with observations of the effectiveness of various compositions at different densities, and with the behavior of the less sensitive explosives.

Fulminate of mercury is by far the most important of the substances used in initiating compositions. It is the chief component of every detonating composition in common use, and, either alone or mixed with other substances, is found in a large number of the initiators proper, particularly those for percussion firing. Its relative importance is gradually becoming less, to be sure; non-fulminate compositions are coming to be used more and more for initiation in primers and, since 1907, when Wöhler and Matter announced the existence of more effective detonating agents, it has no longer been true that without it the valuable organic explosives could not be used.

Fulminate of mercury results from the action of alcohol upon a solution of mercury in an excess of nitric acid. It is a white crystalline substance; commercial fulminate, however, frequently has a grayish or brownish cast due to traces of resinous substances formed during the reaction, or possibly to enclosed particles of finely-divided mercury. It is very slightly soluble in water, somewhat more so in alcohol, and very soluble in pyridine and in aqueous potassium cyanide; the latter two solvents may be used for purification if desired, but it is usual to use the compound as originally formed, after thorough washing with cold water to remove all traces of acid, and drying.

The specific gravity of fulminate is 4.4; when merely tapped down, however, its apparent density is only about 1.7, the density at which it is usually used is around 2.2, corresponding to a loading pressure of 250 kilograms per square centimetre, or 3500 pounds per square inch. (Marshall, p. 512.) If subjected to great pressure, it cannot be exploded by flame, but will apparently detonate with excellent effect if subjected to the impulse obtained from another detonation. When heated, even unconfined, it detonates at from 150° C. to 200° C., depending on the rapidity of heating; the violence of its action is greatly increased by slight confinement. The sensitiveness to impact is dependent on the size of crystals and upon experimental conditions; Will found the blow given by a 2-kilogram weight falling 2 centimetres to be sufficient. (Brunswig, p. 26.) It is, therefore, too sensitive as well as too expensive for use as a main charge—its only employment is in the initiating system.

Fulminate of mercury, as well as the compositions of which it is a constituent, has several undesirable qualities. It deteriorates rather easily, especially in the presence of moisture; in Austria there is an official regulation that detonators are to be stored over fused calcium chloride. Temperatures such as those often encountered in the tropics are of themselves sufficient to produce rather loss of effectiveness, apparently even in the absence of moisture. A moisture content of one per cent. is usually enough to make it ineffective, the explosive qualities being regenerated again upon drying; Storm and Cope found, however, that 0.75 per cent. moisture in 80/20 mercury fulminate-potassium chlorate detonator charges weighing 1.44 grams, caused a negligible reduction in strength as shown by the sand test; in the case of detonator charges consisting of the same fulminate-chlorate mixture superposed on an equal weight of TNT, exposure to an atmosphere saturated with moisture at laboratory temperature resulted in incomplete detonation of the combined charge. (Tech. Paper 125, p. 61.) Mercury fulminate attacks both copper and brass in the presence of moisture, cuprous fulminate, together with zinc fulminate in the case of brass, is formed, and metallic mercury is set free;[3] the action is sometimes sufficient to eat through thin containers, and, if the brass has not been properly annealed, cracking will result. The new fulminates formed are in themselves brisant explosives, nearly equal in effectiveness to mercury fulminate itself, but they are less stable, and are considered by some to be dangerously sensitive. Finally, mercury fulminate is very dangerous to handle and is expensive.

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[3] If mercury fulminate and either zinc or copper are treated with boiling water, metallic mercury is set free, and zinc or copper fulminate, as the case may be, is formed.

Lots of fulminate of mercury obtained from different manufacturers, and even different lots obtained from the same plant, differ materially in their liability to deteriorate; this matter does not seem to have been studied thoroughly. (Marshall, p. 511.) The differences are such as not to be detected in the methods of inspection now in use. Some explosive chemists of to-day believe, in fact, that Howard, who discovered this compound in 1799 and was the first to describe a method for its production, consistently made better fulminate than any one has been able to manufacture since.

Initiators in electric primers, and to a large extent those in electric detonators, consist of finely-divided dry guncotton, of a mixture of dry guncotton and meal powder, or of some other highly-inflammable composition. This material, being soft, is practically insensitive to shock under the conditions of use and the danger of deterioration is considerably less. Largely as a matter of manufacturing convenience, the fulminate composition used in the detonator charge may also be used in the initiator.

Mercury fulminate when used alone is too quick-acting for good results in percussion primers, whether they are for the direct ignition of the propellant or of an ignition charge. From the very first the custom has been to mix with the fulminate other substances which at once decrease the violence of the explosion and add to its heat; the percentage of fulminate used has steadily decreased as time passed, and the content in most modern mixtures does not exceed 20 per cent. (Marshall, p. 504.) Saltpeter, sulphur, and meal powder were formerly mixed with the fulminate in various proportions, and powdered glass was frequently added to increase sensitiveness, which was very likely to diminish quickly because of the hygroscopic properties of the saltpeter. At the present time, potassium chlorate and antimony sulphide (obtained by powdering the sulphide occurring naturally as "stybnite," after purification by liquation if necessary) are used almost exclusively; in these mixtures, antimony sulphide acts as a fuel, the chlorate furnishes the oxygen necessary for its combustion, and the fulminate by its explosion raises the temperature high enough to start the combustion in the first place. The antimony sulphide, which comes in hard, sharp-edged particles, also contributes to the sensitiveness of the composition in the same manner as powdered glass did in earlier mixtures; the decomposition products of antimony sulphide are soft, however, and do not erode the bore like powdered glass.

Work upon the development of primer compositions which contain no fulminate of mercury or other substance in itself explosive has been going on for a number of years. The earliest of these contain potassium chlorate and antimony sulphide, together with some other fuel which will react readily with the chlorate upon impact, and thus produce the heat necessary for combustion of the less reactive sulphide. From 10 to 35 per cent. of powdered sulphur was usually used as this second fuel. These mixtures showed a tendency to decompose gradually and the results obtained were very erratic; the output of a plant would be excellent for a time, and then, for some unaccountable reason, a markedly inferior composition would be produced. It now seems that the erratic results were due to improper methods of inspection, or even no inspection, of the ingredients, with the result that impurities fatal to stability were unknowingly introduced; Cushman has pointed out, for example, that under the methods commonly used for testing stybnite, an antimony sulphide content reported as above 98 per cent. might actually be below 80,[4] and sometimes there was no analysis of the raw materials. Since commercial potassium chlorate may contain traces of chlorate, hypochlorite, or bromate—all much less stable than the chlorate—or of the hygroscopic sodium chlorate, it is easily seen that differences in the raw materials themselves from lot to lot would readily cause variations. Even with an ideal inspection system, however, the sulphur was sure to be a source of deterioration; it is well established that finely-divided sulphur, in the presence of air and moisture, tends to oxidize with the final formation of sulphuric acid, which, of course, will attack the other constituents of the mixture and the container.

The great problem then was to find a fuel which would react readily with the chlorate as result of the heat generated by a blow, but which would be stable under the conditions to be expected in service. Of a large number of substances tried, lead sulphocyanate (or thiocyanide—the lead salt of HSCN) has proved to be the most valuable, and compositions made up with it have given excellent results. It decomposes, to be sure, in the presence of considerable moisture—a mixture containing it will quickly "go sour" on a hot day—but after loading and drying the sulphocyanate compositions seem to promise a long effective life. An excellent mixture of this sort is that patented and used by one of the large American companies; this has the following composition:

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[4] "Antimony Sulphide as a Constituent in Military and Sporting Arms Primers," by A. S. Cushman, *Journal of Industrial and Engineering Chemistry*, May, 1918, p. 376.

Potassium chlorate	53 per cent.
Antimony sulphide	17 per cent.
Lead sulphocyanate	25 per cent.
TNT	5 per cent.

A. S. Cushman has developed and patented an interesting method of controlling the ignition effect of the primer composition. (This patent has been assigned to the Government.) It is clear that, even with the closest practicable inspection of raw materials, the ignition effect of one lot of primers may vary from that of another, and that this may have a serious effect upon ballistics in the case of small-arms. By substituting for the 5 per cent. of TNT in the above composition the same weight of a mixture of litharge (lead oxide) and tetryl, the effectiveness can be adjusted within limits by changing the proportions of the two. The litharge also acts as a "sweetener," and by absorbing any acids formed by slight deterioration prevents them from attacking the constituents still unchanged. Lead sulphocyanate, for example, gives a very slight acid reaction when moistened; litmus shows its mixture with litharge to be neutral.

The initiator for percussion detonators may either be of the same composition as the detonator charge, or may be along the lines of the priming compositions just described. If there is an air-gap between the initiator and the detonator, the latter type is probably to be preferred, since more heat is generated and the initiating action continues longer, thus making for more certain action; in this case, the fulminate content usually runs higher than in the true primer compositions, in order to obtain somewhat increased sensitiveness. The non-fulminate compositions are at present not in favor for this purpose, largely because those tried in the past were not reliable after storage, and since the amount of fulminate is small as compared with the total amount in the system; it is possible that the new improved types may show sufficiently good results to overcome this prejudice.

In detonating charges, fulminate of mercury is often used alone, but manufacturers of commercial detonators have been accustomed to introduce a small percentage of potassium chlorate to reduce the quantity of the more expensive fulminate used and to get a composition running more freely in the loading machines. There was a decided difference of opinion between the various authorities as to the influence of the chlorate upon effectiveness, until, in 1916, Storm and Cope demonstrated that the addition of chlorate up to 20 per cent. steadily improved the action. (Tech. Paper 125, p. 46.) Taylor and Cope then showed that there are a number of oxidizing agents which increase the detonating ability of fulminate, principally the salts of oxyhalogen acids, and oxides and nitrates of heavy metals whose decomposition results in free metals; alkali and alkali earth nitrates, and heavy metal oxides which reduce to lower oxides are ineffective. (Tech. Paper 162, pp. 12–14.) It seems improbable, however, that potassium chlorate will be replaced in this use. The same two investigators, following Wöhler's work, also showed that small accelerating charges of lead azide and silver acetylide caused a considerable increase in the efficiency of the fulminate. (Tech. Paper 162, p. 16.)

A variation of the mercury fulminate detonator in common use in commercial work is the "reinforced" detonator, in which about half of the fulminate composition is replaced by a nitroaromatic explosive, usually tetryl or TNT; the part of the charge nearest the fuse (which fills the same function as the initiator) still consists of fulminate or a fulminate-chlorate mixture. The explosives are in contact, and are given greater confinement by means of a copper shell fitting neatly within the detonator shell and pressed on the charge; this results in increased efficiency of the fulminate, because it attains its maximum velocity of detonation more quickly, and more of its energy is compelled to act upon the second order explosive. (Tech. Paper 125, p. 47.) This type of detonator is somewhat more powerful, size for size, than the ordinary kind. There may be more danger of deterioration because of the contact between the two explosives; the usual deterioration of the fulminate may also result in the detonator becoming ineffective more quickly, because of the small amount of fulminate used. (Marshall, p. 506.)

Lead azide[5] appears likely to replace fulminate of mercury as a detonating agent. When finely divided, it is considerably less sensitive to shock than fulminate, it is far more effective as a detonating agent, its sensitiveness and effectiveness are apparently not affected seriously by moisture, at any rate not in the quantities likely to occur, and, instead of becoming "dead pressed," its effectiveness increases with density of loading up to the highest value attainable in practice, its sensitiveness to ignition remaining practically unchanged. No report upon its stability under all conditions has been published, but from the data available it seems to be much better in this respect than fulminate of mercury. Large crystals are likely to be formed, unfortunately, which can detonate on the slightest shock even under water; several accidents of this sort have already occurred. If adopted, it is probable that the reinforced detonator described above will be used, substituting lead azide for the fulminate composition. (Marshall, p. 511.) The Germans made some use of lead azide detonators during the late war, apparently with excellent results.

Little can be said about the future of the organic detonating agents; those proposed so far appear to be too sensitive to shock and too liable to deterioration of one sort or another to be of any practical value for military use. The mere fact that there are organic substances which are more effective detonating agents, weight for weight, than any of the metal compounds is nevertheless important, in that it shows that there is a possibility of finding somewhere among the organic compounds, with their wide range of properties, a detonating agent more useful than any we now know.

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HALL, C., and HOWELL, S. P.: "Investigations of Detonators and Electric Detonators." Bulletin 59, Department of the Interior, Bureau of Mines, Government Printing Office, 1913.

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[5] The lead salt of hydronitric acid, HN_3. These salts are also known as nitrides, hydronitrides, and as trinitrides.

STORM, G. G., and COPE, W. C.: "The Sand Test for Determining the Strength of Detonators." Technical Paper 125, Department of the Interior, Bureau of Mines, Government Printing Office, 1916.

TAYLOR, G. B., and COPE, W. C.: "Sensitiveness to Detonation of Trinitrotoluene and Tetranitromethylanilin." Technical Paper 145, Department of the Interior, Bureau of Mines, Government Printing Office, 1916.

TAYLOR, G. B., and COPE, W. C.: "Initial Priming Substance for High Explosives." Technical Paper 162, Department of the Interior, Bureau of Mines. Government Printing Office, 1917.

An excellent bibliography of the subject of detonation appears in Technical Paper 162.

Physical Constants of Aniline.—Certain physical constants of pure aniline have been determined by C. L. KNOWLES (*Jour. Ind. and Eng. Chem.*, 1920, xii, 881–883). The freezing point is 6.24° *below* zero C.; the boiling point 184.32° to 184.39° C. at a pressure of 760 mm. of mercury; the specific gravity 1.0268 (both the aniline and the water being at a temperature of 15° C.); the index of refraction 1.5850 at 20° C. The purity (in per cent.) of a sample of aniline may be calculated by multiplication of its freezing point (° C.) by the factor 1.41, and addition of the product to 108.79.

J. S. H.

Asbestos in the United States. (*U. S. Geological Survey Press Bulletin No. 461,* December, 1920.)—The United States now obtains most of its high-grade, long-fibre asbestos from Canada, but geologists of the Geological Survey hope that large deposits which will yield material of good quality may yet be found in the Western States, especially in Arizona, where asbestos of unusually long fibre and silky texture has been discovered.

In the Apache and San Carlos Indian reservations, in Arizona, asbestos is found associated with rocks known by geologists as the Apache group, which is made up of several formations. The principal deposits are in the Salt River region, where the Apache group is represented chiefly by beds of quartzite and limestone, which are at many places invaded by diabase, an igneous rock. Throughout this area much diabase has been injected into beds of limestone, and the asbestos is found near the contact of the limestone with the diabase. Places where the limestone has been much broken by the diabase have been particularly favorable for the formation of asbestos. The asbestos is invariably associated with serpentine, a greenish mineral that is in some deposits in other regions mottled like a serpent's skin, and although serpentine occurs at many places without asbestos, serpentine "float" fragments of it that lie loose on the surface, having been washed out from its outcrop, are a valuable aid to the prospector for asbestos. In this region asbestos itself is also generally found as float for a considerable distance below its outcrop.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE CARBONIZATION OF LUBRICATING OILS.[1]

[ABSTRACT.]

THE principal reason for writing this circular was to give detailed descriptions of the methods used for the determination of the " Conradson carbon residue " and the " Waters carbon " of oils used to lubricate internal combustion engines.

After brief accounts of the nature and effects of " carbon " deposits in the engine, and of the chemical nature of petroleum oils, the theories concerning the causes of the deposition of this material are discussed in connection with somewhat detailed accounts of the oxidation and cracking of petroleum oils.

The Waters and Conradson tests are described in detail, together with the apparatus employed, and brief accounts are given of a few other methods, including those in which the oil is distilled.

The circular closes with a condensed summary of several more or less controversial papers that have been published elsewhere.

THE ELECTRIC-ARC WELDING OF STEEL: THE PROPERTIES OF THE ARC-FUSED METAL.[2]

By Henry S. Rawdon, Edward C. Groesbeck and Louis Jordon.

[ABSTRACT.]

A FUSION weld is fundamentally different from all other types in that the metal of the weld is essentially a casting. The arc-fusion weld has characteristics which are peculiar to it alone. A knowledge of the mechanical properties of the arc-fused metal which is added during the process of welding is fundamental in the study of arc-welding. The mechanical properties as revealed by stressing in tension were determined upon specimens (0.505 in. diameter, 2 in. gage length) cut from blocks of arc-fused metal prepared under conditions similar to those met in welding. Additional specimens were also prepared by expert welders outside of the Bureau and submitted for comparison with those prepared by the Bureau.

Two types of electrodes, a " pure " iron and a low-carbon

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* Communicated by the Director.

[1] Circular No. 99.

[2] Technologic Paper No. 179.

steel, were used. During fusion the composition changes considerably as the carbon and other elements are eliminated. The two types of electrodes become very much alike in composition. In each case a considerable percentage of nitrogen is taken up.

The mechanical properties of the arc-fused metal as measured by the tension test are essentially those of an inferior casting. The most striking feature is the low ductility of the metal. All of the specimens examined (about 70) showed evidence of unsoundness in their structure, tiny enclosed cavities, oxide inclusions, and lack of intimate union. These appear to be a necessary consequence of the method of fusion as now practiced. They determine almost entirely the mechanical properties of the metal. The observed elongation of specimens under tension is due to the combined effect of the numerous unsound spots rather than to the ductility of the metal.

The material is, however, inherently rather ductile, as may be shown by the changes produced in its microstructure by cold-bending.

A characteristic feature of the microstructure of the arc-fused metal is the presence of numerous microscopic plates within the ferrite grains. These persist in the metal upon prolonged heating, for example, 6 hours at 1000° C. in vacuo were not sufficient to remove them. The various lines of evidence available indicate that they are related to the nitrogen-content of the metal.

The microscopic examination indicates that there is but little, if any, relation between these so-called "nitride plates" and the path of rupture produced by tensional stresses. The effect of the grosser imperfections of the metal is so much greater than any possible effect of these plates in determining the mechanical properties that the conclusion appears to be warranted that this feature of the structure is a matter of relatively minor importance in ordinary arc welds.

Judged from the properties of the metal after fusion, neither type of electrode used appears to have a marked advantage over the other. The use of slight protective coatings on the electrodes does not appear to affect the mechanical properties of the arc-fused metal materially in any way. The specimens were prepared in a manner quite different from that used ordinarily in electric-arc welding and so do not justify specific recommendations concerning methods of practice in welding.

THE USE OF AMMONIUM PERSULPHATE FOR REVEALING THE MACROSTRUCTURE OF IRON AND STEEL.[3]

By Henry S. Rawdon.

[ABSTRACT.]

Ammonium persulphate is a widely used etching reagent for copper alloys, but the advantages of its use with iron and steel have been almost entirely overlooked. The article describes the method of application of the reagent and gives photographs to illustrate typical results obtained. Ammonium persulphate decomposes upon the addition of water, so that the action of the reagent is that of a weak acid intensified by the presence of oxygen. Chemical unhomogeneity is readily shown by the reagent, but the most characteristic feature in its action is the readiness with which it reveals the crystalline condition of the material.

RESONANCE POTENTIALS AND LOW VOLTAGE ARCS FOR METALS OF THE SECOND GROUP OF THE PERIODIC TABLE.[4]

By F. L. Mohler, Paul D. Foote and W. F. Meggers.

[ABSTRACT.]

Measurements of potentials of inelastic electron impacts have been made in vapors of mercury, cadmium, zinc, and magnesium, using a four-electrode vacuum tube. In addition to the resonance and ionization potentials observed in previous work at potentials corresponding to the spectral frequencies $1.5S - 2p_2$ and $1.5S$ respectively, a second resonance potential has been observed in each case. This corresponds to the frequency $1.5S - 2P$. A spectroscopic study of the low-voltage arc in magnesium proves the existence of the line $1.5S - 2p_2$, $\lambda = 4571$ *A* as the single-line spectrum. This is contrary to the conclusion arrived at by McLennan from a similar experiment and removes a difficulty in the theory of resonance potentials and low voltage arcs. The present work shows that the spectral relations of critical potentials are similar for all metals of the second group.

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[3] Scientific Paper No. 402.

[4] Scientific Paper No. 403.

Sulphur Dioxide as an Oxidizing Agent.—WILLIAM WARDLAW, FRANCIS H. CLEWS, and SIDNEY R. CARTER (*Jour. Chem. Soc.*, 1920, cxvii, 1093–1103, 1241–1247) have made a study of the oxidizing action of sulphur dioxide on ferrous salts. While sulphur dioxide usually acts as a reducing agent, it also possesses oxidizing powers. Thus, if a solution of ferrous chloride in 33 per cent. hydrochloric acid be treated with sulphur dioxide, the iron is oxidized to the ferric state, and the sulphur dioxide is reduced to elementary sulphur; for this solution the optimum temperature is 95° C. The oxidation does not occur at 95° C. if the solution of ferrous chloride contain less than 165 grams of free hydrogen chloride per litre. The entire ferrous iron content of the solution is not oxidized. The maximum amount of the total iron changed to the ferric state was 9.5 per cent.; this yield was obtained in a sealed tube experiment. Solutions of iron in 33 per cent. hydrochloric acid, containing from 10 to 18.3 per cent. of their total iron as ferric iron, and kept at a temperature of 115° C., showed no evidence of either oxidation or reduction when a mixture of sulphur dioxide and hydrogen chloride, containing equal quantities by weight of the two gases, was passed through the solution for several hours. Under these conditions, solutions containing more than 18.3 per cent. of their total iron in the ferric state were slowly but incompletely reduced.

Study was also made of the action of sulphur dioxide on the phosphates of iron in the presence of concentrated phosphoric acid. No evidence was obtained that sulphur dioxide can act as a reducing agent on ferric phosphate in the presence of concentrated phosphoric acid. Sulphur dioxide oxidized ferrous phosphate to ferric phosphate in the presence of concentrated phosphoric acid, even in mixtures in which the ferric salt already formed a high per cent. of the total iron. Whether all the ferrous iron may ultimately be oxidized to the ferric state is uncertain.

J. S. H.

Digestion of Starch by Diastase.—The value of a malt is determined by its power to digest starch. EDWARD I. ROSENBLUM (*Jour. Soc. Chem. Ind.*, 1920, xxxix, Trans., 311–313) finds that the amount of acid salts present in starch varies with the sample; consequently the hydrogen ion concentration of the starch varies with the sample. The ability of the malt to digest starch (diastatic power) is influenced by the hydrogen ion concentration of the medium, and is at a maximum when the medium is faintly acid to methyl red but is alkaline to methyl orange. This optimum reaction may be obtained by addition of ammonium dihydrogen phosphate; usually 0.5 per cent. of this salt is the correct amount to be added to the medium.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

TOXICITY OF BARIUM CARBONATE TO RATS.[1]

By E. W. Schwartze.

[ABSTRACT.]

A SERIES of experiments on the toxicity of various substances to rats and their suitability for poisoning these animals was undertaken by the Bureau of Chemistry as part of the rat-extermination work of the Department of Agriculture. The results of the tests with barium compounds brought out the following facts:

Lethal Dose for Rats.—Barium chlorid, subcutaneously, 45 to 89 mg. per kilo, by stomach tube, 350 to 535 mg. per kilo; barium carbonate, per os, 630 to 750 mg. per kilo. On the basis of the barium content, the carbonate is about two-thirds as active as the chlorid when administered per os.

The average intake of food, both poisoned and unpoisoned, by hungry white rats, was one-hundredth of their body weight.

Twenty per cent. of barium carbonate in the rat bait was found to be an efficient concentration. With this percentage a rat is required to eat only one-third or three-eighths of a meal of average size, or one three-hundredth-and-twentieth to one two-hundred-and-sixty-sixth of its own weight, in order to secure the ingestion of a lethal amount. With this concentration, many of the rats die within the first 24 hours, the chief factor being the consumption of an amount larger than the minimum efficient lethal dose.

WEIGHT VARIATION OF PACKAGE FOODS.[2]

By H. Runkel.

[ABSTRACT.]

THE BUREAU OF CHEMISTRY has made a study of methods of packing foods under commercial conditions to determine the

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* Communicated by the Chief of the Bureau.

[1] *U. S. Dept. Agr. Bull. 915*, issued Nov. 12, 1920.

[2] *U. S. Dept. Agr. Bull. 897*, issued Nov. 15, 1920.

amount of normal variation in weight. From information collected at 126 factories, suggested specifications for good commercial practice of hand weighing have been worked out. On the basis of these specifications and Bureau of Standards' tolerances, values have been assigned to constituent errors, and these errors combined according to Least Squares methods.

The figure obtained by this combination is termed the calculated maximum error of good commercial practice. According to observations taken in factories packing such packages, the chance of occurrence of variations greater than the calculated maximum error is one in more than one thousand. The calculated maximum errors in good commercial practice as determined in the bulletin are given in the following table:

Size of package.	For net weighing.		For gross and tare weighing.	
	On single packages.	On the average of a representative sample.	On single packages.	On the average of a representative sample.
	Ounces.	*Ounces.*	*Ounces.*	*Ounces.*
2-ounce	0.150	0.097	......	......
3-ounce	.150	.097	......	......
4-ounce	.150	.097	......	......
8-ounce	.150	.097	......	......
1-pound	.213	.106	......	......
2-pound	.360	.145	......	......
3-pound	.363	.148	......	......
4-pound	.409	.194	......	......
5-pound	.409	.209	......	......
10-pound	.544	.373	0.674	0.414
25-pound	5.41	2.68	7.49	3.34
50-pound	5.41	2.68	7.73	3.57
75-pound	5.65	2.92	7.73	3.57
100-pound and above	5.65	2.92	8.29	4.13

A study is also made of the variations produced by weighing.

SOME PROTEINS FROM THE MUNG BEAN, PHASEOLUS AUREUS ROXBURGH.[3]

By Carl O. Johns and Henry C. Waterman.

[ABSTRACT.]

THE mung bean contains about 21.74 per cent. of protein (N × 6.25). Experiments with aqueous sodium chloride in various concentrations indicated a 5 per cent. solution as the most effective extractant; it dissolved 19.0 per cent. of protein from the finely ground seed.

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[3] Published in *J. Biol. Chem.*, 44 (1920), 303.

The 5 per cent. sodium chloride extract yielded two globulins, designated the α- and β-globulins, by fractional precipitation with ammonium sulphate and subsequent purification of the fractions. The yields were 0.35 and 5.75 per cent., respectively, computed on the basis of the dry material extracted. Traces of albumin, also, were obtained from extracts from which all the globulin had been precipitated by prolonged and repeated dialysis. The albumin remained in solution during the dialysis and was separated by slightly acidifying and coagulating at 45° C. The yield of the albumin was from 0.02 to 0.05 per cent. of the weight of the bean meal.

Analyses showed marked differences in the nitrogen and sulphur content of the three proteins. The globulins were still further distinguished from each other by marked differences in their percentages of the basic amino-acids, determined by Van Slyke's method. The β-globulin contained so little cystine that that remaining undecomposed after hydrolysis escaped precipitation by phosphotungstic acid and could not be determined by Van Slyke's method.

SOME AMINO-ACIDS FROM THE GLOBULIN OF THE COCONUT AS DETERMINED BY THE BUTYL ALCOHOL EXTRACTION METHOD OF DAKIN.[4]

By Carl O. Johns and D. Breese Jones.

[ABSTRACT.]

THE products obtained by the hydrolysis of coconut globulin by boiling with 20 per cent. hydrochloric acid for 27 hours were subjected to the butyl alcohol extraction method of H. D. Dakin.

Attention was confined chiefly to the amino-acids remaining in the aqueous solution after the extraction. The following values were found: Glutaminic acid, 19.07 per cent.; aspartic acid, 5.12 per cent.; alanine, 2.67 per cent.; and serine, 1.76 per cent. No hydroxyglutaminic acid or glycine could be detected.

From the amino-acids extracted by the butyl alcohol 5.54 per cent. of proline, and 0.64 per cent. of leucylvaline anhydride were isolated.

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[4] Published in *J. Biol. Chem.*, 44 (1920), 283.

Agricultural Lime.—R. C. COLLISON of the New York Agricultural Experiment Station at Geneva states in *Bulletin 478* of that station that at least 50 to 75 per cent. of the soils of that state would be distinctly benefited by the addition of suitable basic material. The following substances are used for this purpose: Burned lime, hydrated lime, ground limestone, and lime by-products; usually the most economical is a good grade of ground limestone with a calcium carbonate equivalent of over 90 per cent. If ground limestone be applied at the rate of 500 to 1000 pounds per acre, it should all pass a 40-mesh screen; if applied at the rate of 2 or more tons per acre, it need only pass a 10-mesh screen. The smaller amount should be applied yearly, while the heavier treatment is required but once every three to five years. Magnesium limestone may be used for agricultural purposes. Limestone screenings and crusher dust (a by-product in the manufacture of crushed stone) frequently are a fair grade, cheap material suitable for use in liming soils.

J. S. H.

Alcohol as a Motor Fuel.—Preliminary researches by H. B. DIXON on the use of alcohol as a motor fuel are described in *Jour. Soc. Chem. Ind.*, 1920, xxxix, Review, 355. Alcohol was found to possess most of the properties which are characteristics of a good motor fuel. Its caloric value is lower than that of petrol, but it may be used under higher pressures than the latter. This property of high ignition temperature under compression is changed but little by admixture of 20 per cent. of benzene or of petrol. Such a mixture starts readily in the cold, and runs very smoothly in an engine.

J. S. H.

Colloids.—From a critical study of colloids, H. D. MURRAY (*Science Progress,* 1920, xv, 234–242) concludes that the deepest insight into dispersoid systems has been given by the phenomena of coagulation, and that future knowledge of colloids will probably come from that direction.

J. S. H.

Natural Deposits of Potash.—H. D. RUHM urges that search for natural deposits of soluble potash salts be made in the salt fields of New York, Ohio, and Michigan by means of core drilling. Deposits of potash salts, similar to those of Stassfurt, are likely to exist in any salt beds of considerable thickness. In a search of this nature, a saturated brine must be used for the liquid in the core drills. (*Jour. Ind. and Eng. Chemistry,* 1920, xii, 837–840.)

J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

STATE LAWS ON USE OF ELECTRICITY IN COAL MINES.

By L. C. Ilsley.

THIRTY of the States in the Union have coal mines, and twenty-eight have regulations or laws governing the operation of coal mines. Pennsylvania was the first to have a coal-mining law of any kind in 1869. By 1890, thirteen States had coal-mining Statutes. Before 1890, electricity was little used in mines, and these early codes contain practically no provisions regulating its use. Since that date the application of electricity in coal mining has made tremendous progress and now twenty-one States make some reference in their coal-mining codes to the use of electricity. The rapidity with which electrical equipment has entered into the many phases of mining has, however, greatly exceeded the advance of regulations governing its use. Even the best electrical mining codes in force need modernizing and some States have even neglected to mention the use of electricity in their mining laws.

In general, the best way to obtain satisfactory electrical equipment for mine service, and to insure its proper installation, inspection, and maintenance, is for each coal-mining State to make and enforce fundamental rules and regulations relating to the use of electricity and electrical equipment in and about coal mines.

Bureau of Mines Technical Paper 271, "Mining Laws on Use of Electricity in Coal Mines," presents the results of a study of the different State codes.

STORAGE BATTERY LOCOMOTIVES.

By L. C. Ilsley and H. B. Brunot.

IN the past ten years the use of storage-battery locomotives in coal mines has rapidly increased. Their use tends to do away with trolley wires except on main haulage roads, hence the danger of electric shock from uncovered trolley wires is lessened and the wires need not be extended into the gaseous parts of the mine. Storage-battery locomotives are, however, a possible menace to safety. Originally they were not designed for use in gaseous places, but their use in such places has gradually increased because the danger was not generally recognized.

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* Communicated by the Director.

In 1916, the Bureau of Mines, in coöperation with manufacturers of locomotives and batteries, prepared tentative specifications covering minimum safety requirements.

As specific information on many of the points involved was necessary for intelligent revision of the specifications, the bureau began laboratory and field investigations of possible dangers from headlights, from abrasive sparks struck off by brakes and wheels, and from battery equipment, with a view to the elimination of unsafe features discovered. Also, application was made of information derived from previous work on the testing of coal-cutting equipment and miners' lamps.

In July, 1919, another conference of manufacturers was held at the Pittsburgh Experiment Station. A schedule for the establishment of a permissible list of storage-battery locomotives was prepared and after minor additions was published in August, 1919, as Schedule 15 of the Bureau of Mines.

Technical Paper 264, "Preliminary Investigations of Storage Battery Locomotives," describes the development of the specifications that led to the preparation of Schedule 15, and contains data obtained through the preliminary investigation made in order to assist manufacturers who were developing apparatus.

ANALYSES OF AIR FROM BURNING BUILDINGS.

By S. H. Katz.

The Bureau of Mines is coöperating with municipal fire departments for the purpose of obtaining information regarding composition of the air in burning buildings. The gas-mask laboratory of the Bureau's experiment station at Pittsburgh sent vacuum bottles for taking samples to fire chiefs in twenty-five cities. Thus far, eleven samples have been received by the laboratory. Results of analyses and pertinent data regarding these samples are given in a paper recently issued by the bureau.

Eight of the eleven samples contained no carbon monoxide;

seven of the eight were taken above the ground level and one below ground. One sample taken above ground contained 0.03 per cent. carbon monoxide, and this quantity is not dangerous to breathe for a limited time. Of the three samples taken below ground, one contained no carbon monoxide; the other two contained 0.10 and 0.35 per cent., respectively. This indicates that in a burning building the hazard from carbon monoxide is much greater below the ground level. The cause undoubtedly lies in the poorer ventilation that is usually found in cellars or basements. Abundance of ventilation provides the necessary air for complete combustion, or if incomplete combustion does occur, the carbon monoxide generated by the fire is greatly diluted with fresh air and swept away by the current. It may be noted that the highest proportion of carbon monoxide was found in a cellar where a fire was burning among piled cases. The difficult access of air to the burning parts facilitated the formation and liberation of carbon monoxide. The smoke here was very light and no difficulty was experienced in breathing. Some of the air containing dense smoke showed little change from normal air by analysis. Thus the density of smoke or the irritation and difficulty it causes in breathing are no indication of the presence of poisonous gas. None of the samples shows important deficiencies in oxygen. It is hoped that in time more air samples from burning buildings will be analyzed in order to extend the information given.

RECOVERABLE OIL IN BY-PRODUCT SANDS AND OUTCROPS.

By A. R. Elliott.

A survey of the oil districts of California has been made by the bureau in order to ascertain whether the visible masses of wasted oil-bearing sands would be a profitable source of supply. From the data collected, it is estimated that 2,359,100 barrels of oil, valued at more than $3,500,000, could be obtained from the sand piles about producing wells and from the outcroppings in the vicinity of the fields. Also, many times that amount of oil scattered over nearly the total oil-producing area, might be recovered from seepage—that is, the oil permitted to soak into the ground or spread over the surface.

The character of these wastes and possible methods of recovery are given in a recent report issued by the bureau.

STENCHES FOR DETECTING LEAKAGE OF GAS.

By S. H. Katz and V. C. Allison.

Leakage in the distribution of natural gas or artificial illuminating gas is a frequent cause of loss of life and property. The addition of a stench to the gas for detecting leaks would result in a material reduction of loss by leakage, thus increasing safety and promoting economy. Blue water gas is very dangerous, as it is almost odorless and contains 35 per cent. carbon monoxide. Some German cities require by law the addition of stench to this gas. Also, natural gas is comparatively odorless, and very difficult to detect, and use of stench would give warning in time to avert many of the dangerous explosions that occur from leaking gas. Technical Paper 267 of the bureau, entitled "Stenches for Detecting Leakage of Blue Water Gas and Natural Gas," gives the properties of various stenches examined, their market prices, and methods for introducing them into gas mains.

On the Variation of Thermal Conductivity During the Fusion of Metals. Seibei Konno. (*Phil. Mag.*, November, 1920.)—Hitherto there has been a paucity of experimental investigations with regard to the conduct of thermal conductivity of metals, or indeed of any substances, when the change from solid to liquid takes place. E. F. Northrup and H. Tsutsumi have found that the electrical conductivity of metals falls sharply and largely in fusion. According to the electron theory, both conductivities should follow the same course. In many other cases this has been verified. It is of interest to discover whether this relation holds true also at the melting-point. The Japanese physicists find as follows:

"1. The thermal conductivity of tin, lead, zinc, and aluminum decreases with the rise of temperature up to their melting-point.

"2. The thermal conductivity of these metals decreases abruptly during melting.

"3. The thermal conductivity of (solid) bismuth and antimony slightly decreases at first, and then increases a little.

"4. During melting the conductivity of bismuth considerably increases, and that of antimony seems to increase only slightly.

"5. The thermal conductivity of all liquid metals here investigated decreases but slightly with the rise of temperature.

"6. The above changes of thermal conductivity are similar to those of electric conductivity for the same metals."

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of a Special Meeting held Wednesday, December 8, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 8, 1920.

A special meeting of The Franklin Institute held in pursuance to the following notice, dated November 17, 1920:

> A special meeting of The Franklin Institute will be held on the eighth day of December, 1920, at four-fifteen o'clock, in the Hall of the Institute, for the purpose of taking action upon the bequest to The Franklin Institute, contained in the last will and codicil of the late Henry W. Bartol.

was held this afternoon at 4.15 o'clock in the Hall of the Institute.

The President, Dr. Walton Clark, stated that the purpose of the meeting was that indicated by the notice of the meeting sent to all members and recognized Mr. W. C. L. Eglin, who made the following motion:

> *Resolved,* That the bequest and trust, with all conditions pertaining thereto, contained in the last will and testament of Henry W. Bartol, deceased, dated the 22nd day of September, A. D. 1911, and the codicil thereto dated the 29th day of November, A. D. 1918, both probated in the office of the Register of Wills in and for the city and County of Philadelphia as of the ninth day of October, A. D. 1920, be and the same are hereby accepted by The Franklin Institute of the State of Pennsylvania.

This motion was seconded by Mr. E. H. Sanborn and unanimously adopted.

The following gentlemen, members of the Institute in good standing, whose signatures follow, constituting more than a quorum, were present:

W. C. L. Eglin
Kern Dodge
R. W. Lesley
Henry Howson
Edward H. Sanborn
Charles E. Brinley
Benjamin Franklin
Frederick A. Riehlé
Lawrence T. Paul
Arthur W. Lowe
Monroe B. Snyder
Howard S. Graham
L. F. Rondinella
William Otis Sawtelle
George R. Henderson
William H. Thorne
William J. Haines
Coleman Sellers, Jr.
Gellert Alleman
George A. Hoadley
Alfred W. Gibbs
Nathan Hayward
T. Broom Belfield
Jacob Y. McConnell
Richard L. Binder
Guilliam H. Clamer
Harold Calvert
Walton Forstall
Walton Clark

Adjourned.

R. B. OWENS,
Secretary.

(Proceedings of the Stated Meeting held Wednesday, December 15, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 15, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 4.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The Committee on Nominations, appointed by the President in accordance with the resolution passed at the Stated Meeting held November 17th, last, presented the following list of nominees to be voted for at the Annual Election to be held on Wednesday, January 19, 1921:

For President (to serve one year) Walton Clark.

For Vice-president (to serve three years) Charles Day.

For Treasurer (to serve one year) Benjamin Franklin.

For Managers (to serve three years) Charles E. Bonine, Alfred W. Gibbs, Howard S. Graham, George R. Henderson, George A. Hoadley, Lawrence T. Paul, James S. Rogers, C. C. Tutwiler. On motion duly seconded the nominations were closed.

The paper of the evening on "Some Characteristics of Electron Tubes" was presented by Mr. W. C. White, Electrical Engineer, Research Laboratory, General Electric Company, Schenectady, New York. An account was given of the various uses of electron or vacuum tubes. It was shown that their flexible characteristics and variety of properties make them very useful in laboratories and for engineering tests and developments. In their use, however, for special purposes difficulties are frequently encountered which are due to the properties of the tube and are not commonly known or understood. The more unusual characteristics were described. The subject was illustrated by lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 1, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, December 1, 1920.

MR. CHARLES PENROSE *in the Chair.*

The following reports were presented for first reading:

No. 2744: Republic Flow Meter.
Prof. L. F. Rondinella, Chairman.

No. 2764: Use of the A. C. Electro-Magnet in Surgery.
Mr. Nathan Hayward, Chairman.
No. 2765 and No. 2766 } The Franklin Medal.
Dr. Harry F. Keller, Chairman.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, November 11th, at eight o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Dr. Ulric Dahlgren, A.B., M.S., Professor of Biology in Princeton University, delivered a lecture on the "Production of Motion by Animals." Attention was paid to amoeboid motion, and to motion by means of turgidity, of cilia, and of muscle, and also to the lever systems of motion apparatus. A description was given of the various forms of crawling, swimming, walking, and flying.

The communication was discussed; a vote of thanks was extended to Prof. Dahlgren; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry and Section of Photography and Microscopy.—A joint meeting of the Sections was held in the Hall of the Institute on Thursday evening, December 2nd, at eight o'clock, with Dr. George Crampton in the chair. The minutes of the previous meeting were read and approved.

C. E. Kenneth Mees, Sc.D., Director of the Research Laboratories of the Eastman Kodak Company, Rochester, New York, delivered an illustrated lecture on "The Structure of Photographic Images." The relationship between the size, number, and arrangement of the particles of silver halide in the photographic emulsion and the graininess of the image was discussed. Other factors which modify the image were also considered.

The paper was discussed at length; a vote of thanks was extended to Doctor Mees; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, December 9th, at eight o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were approvevd as read.

John S. Shearer, B.S., Ph.D., of the Department of Physics of Cornell University, Ithaca, New York, presented a communication on "Recent Advances in the Production and Application of X-rays." The newer apparatus and the technic for the production of X-rays were described. An account was given of Lane's work on diffraction by crystals, the X-ray Spectrum, and absorption of X-rays for separate wave lengths. The relation of X-rays to physical theory, to therapy, and to the industries was traced.

The communication was discussed; a vote of thanks was extended to Doctor Shearer; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, December 8, 1920.*)

RESIDENT.

MR. JULIAN D. JONES, Sup't Telegraph and Signals, Eastern Region, Pennsylvania System, Room 152, Broad Street Station, Philadelphia, Pennsylvania.

MR. R. V. TOWNEND, Victor Talking Machine Company, Camden, New Jersey.

NON-RESIDENT.

PROF. ROBERT C. COLWELL, Department of Physics, Geneva College, Beaver Falls, Pennsylvania.

MR. TERRENCE J. FORD, 847 E. Fourth Street, Bethlehem, Pennsylvania.

CHANGES OF ADDRESS.

DR. A. D. CHAMBERS, R.F.D. No. 1, Edgemoor, Delaware.

MR. FRANCIS J. COLE, 640 South Hill Street, Pasadena, California.

MR. HOWARD T. DESHONG, No. 9, Lansdowne Avenue, Lansdowne, Pennsylvania.

MR. KERN DODGE, The Dodge Steel Company, State Road and Hellerman Street, Tacony, Philadelphia, Pennsylvania.

MR. EDWIN FRANK, care Miss Elsa J. Frank, 2300 Grand Avenue, Milwaukee, Wisconsin.

MR. FRANK GITTELSON, 28 East Mt. Vernon Place, Baltimore, Maryland.

DR. JOSEPH S. HEPBURN, Hering Laboratory, Hahnemann Medical College, Philadelphia, Pennsylvania.

DR. CARL HERING, 1317 Spruce Street, Philadelphia, Pennsylvania.

MR. FRED E. IVES, 1327 Spruce Street, Philadelphia, Pennsylvania.

MR. JONATHAN JONES, Tatanager, B-N Railway, India.

MR. LAWRENCE T. PAUL, 105 Liberty Building, Philadelphia, Pennsylvania.

MR. EMILE G. PERROT, 801 Parkway Building, Philadelphia, Pennsylvania.

MR. CARL D. PRATT, 412 West Broad Street, Tamaqua, Pennsylvania.

PROF. WALTER RAUTENSTRAUCH, 43 Exchange Place, New York City, New York.

MR. FREDERICK W. SALMON, Civil and Mechanical Engineer, Richmond, Virginia.

MR. R. JOHN TITZEL, Hamilton Apartments, Norristown, Pennsylvania.

MR. ETHAN VIALL, Barbourville, Kentucky.

MR. EARL H. WELTZ, 122 Broadway, Carney's Point, New Jersey.

NECROLOGY.

Hon. Horace L. Haldeman, 1008 Real Estate Trust Building, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

ANDROS, S. O.—Fuel Oil in Industry. 1919.
ARENDT, M.—Storage Batteries. 1920.
BRANT, W. W.—Galileo. 1918.
CHALMERS, T. W.—Paper Making and Its Machinery. 1920.
CRAIG, E. H.—Oil Finding. No date.
DANIELS, G. W.—Early English Cotton Industry. 1920.
FLEMING, J. A.—Wonders of Wireless Telegraphy. 1919.
HOGBEN, L. T.—Alfred Russel Wallace. 1918.
PURDY, H. F. P.—Diesel Engine Design. 1919.
SILBERSTEIN, L.—Report on the Quantum Theory of Spectra. 1920.

GIFTS.

American Iron and Steel Institute, Annual Statistical Report for 1919. New York City, New York, 1920. (From the Institute.)

Ball Engine Company, Bulletins Nos. S–16, S–20, S–22, S–30, S–36. Erie, Pennsylvavnia, 1920. (From the Company.)

Bartlett, C. O. and Snow Company, Booklet on Ideas. Cleveland, Ohio, 1920. (From the Company.)

Becker Milling Machine Company, Catalogue No. 1. Boston, Massachusetts, 1920. (From the Company.)

Black and Decker Manufacturing Company, Electric Air Compressors, Portable Electric Drills, Electric Valve Grinders. Baltimore, Maryland, 1920. (From the Company.)

Blanchard Machine Company, The Blanchard Grinder. Cambridge, Massachusetts, 1920. (From the Company.)

Blaw—Knox Company, Prudential Steel Buildings. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Buffalo Forge Company, Catalogue No. 460. Buffalo, New York, 1920. (From the Company.)

Card Manufacturing Company, Catalogue No. 30. Mansfield, Massachusetts, 1920. (From the Company.)

Cement Gun Company, Incorporated, Gunite Slabs. Allentown, Pennsylvania, 1920. (From the Company.)

Chicago Bridge and Iron Works, The Water Tower. Chicago, Illinois, 1920. (From the Works.)

Colonial Supply Company, Book 877. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Connecticut Agricultural Experiment Station, Report for the Year of 1919. New Haven, Connecticut, 1920. (From the Experiment Station.)

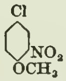
BOOK NOTICES.

Die Zwischenprodukte der Teerfarbenfabrikation. Ein Tabellenwerk für den praktischen Gebrauch. Nach der Patentliteratur bearbeitet von Dr. Otto Lange. 8vo., xxiv–645 pages including index, reference list to German patents and one chart. Leipzig, Otto Spamer; paper bound, M. 135, full bound, M. 150, each plus 40 per cent. bookseller's advance.

"Admirable" is the adjective to be applied to this work, using the word in both its Shakesperian and modern sense, for examination arouses both wonder and praise. The coal-tar intermediates have a practical and a somewhat romantic interest in chemistry. The first tar color, it is true, was produced without distinct recognition of the relation of intermediate substances to the color itself, but very soon the extensive capacity of benzene, its homologues and related substances, to give rise to isomers was recognized, and the minds of chemists were turned to the problem of the structure of these molecules. The solution came out of Germany. In the middle sixties of the last century, Kekulé set forth his theory of the ring structure of benzene and his suggestion of a symbol for it, now the most familiar figure in our works on organic chemistry, and which was adopted as part of the insignia of the Chemical War Service of the United States during the recent war. The views of Kekulé and his co-workers were not at once accepted in the other two nations that were then most active in the chemical industries, England and France. Indeed, many prominent chemists in those countries not only did not accept the views, but they devoted themselves to active antagonism to them, and thus delayed the development of their own coal-tar industries for many years. It is depressing to recall that the first "aniline" color was made in England, but the hint was not taken, and this most important phase of chemical industry passed to another nation that fate had marked for England's greatest rival. Of course, British and French chemists and capitalists cannot be blamed for not reading the future as it has been unfolded to us within the past few years, but they might, at least, have lent more willing eyes and ears to the suggestions that came from beyond the Rhine, instead of which they made merry over what they considered to be the extravagances and hallucinations of the "land of dam'd professors" as Lord Palmerston called Germany. Theodore Weyl, in his work on the "Sanitary Relations of the Coal-tar Colors," written over a score of years ago, and which the present reviewer had the honor of presenting in English text, said in his preface, "Thanks to the coöperation of theory and practice, the coal-tar color industry of Germany has conquered the world," and this sentence expresses the real state of the case. "Die Weltgeschichte ist das Weltgericht," and the great mistakes that have been made in this field in the past, may serve as a warning to the "Allied and Associated Powers" that if they are to render themselves independent in this and other fields of industry, it will be by equal cultivation of the pure and applied phases of science. *"Fas est et ab hoste doceri,"* "it is allowable to learn from the enemy" was an ancient motto fully as applicable now as it was in the days of Ovid.

Turning from these thoughts, awakened by the inspection of Dr. Lange's book, to the book itself, it is best to give some details of its matter and form. It is a splendidly printed volume, with clear type on good paper. The enormous amount of information is made readily accessible by careful classification, largely based on an alphabetical arrangement and supplemented by an extensive index. Thirty-six hundred and thirty seven substances are described, arranged in four series, the derivatives, respectively, of benzene, naphthalene, anthracene and phenanthrene, the first-named comprising the largest number of items and the latter the smallest. Each intermediate is given with its systematic name printed in bold-faced neat type, and in most cases the structural formula also printed neatly and clearly. The reviewer desires to remark in passing that Doctor Lange knows how to write a ring symbol, which is not the case with some distinguished English-speaking and French-speaking chemists. In addition to the above data, brief statements are made as to the methods of producing the intermediates and references to the patent literature, most prominently to the DRP list, but also in many cases to American, British and French lists. In many cases, references to German periodical literature are given. The method of the book can best be exemplified by transcribing one of the items of average extent and fullness of detail, as follows:

726 **DRP. 140 133**
Ann. 182, 110
Ber. 7, 1600;
29, 2599

1-Chlor-3-nitro-4-methoxybenzol 

= $C_7H_6ClNO_2$ = 187,

192 T. 2, 5-Dichlor-1-nitrobenzol + 250 T. Methylalkohol + 114,3 T. Natronlauge (40°) 5 St. unter Rückfluß kochen, den größten Teil des Alkohols abdestillieren und das Produkt aus Sprit umkrystallisieren. Blaßgelbe Prismen, Sch.-P. 94°—96°.

It will be noticed that in the nomenclature the numerical system is followed, and not the older method with prefixes; in accordance with the latter the above compound would be designated, presumably, p-chlor-methoxy-m-nitrobenzene. The Germans still use, unfortunately, the inappropriate termination " ol " for benzene and homologues. Although using not infrequently the o,m,p, signs for the position of substituting groups in the benzene series, Doctor Lange has practically discarded the alpha and beta prefixes in the naphthalene groups, using a strictly numerical system. Thus, the substance commonly designated in English text-books as alpha-naphthol, is here designated as 1-naphthol, and substitutions in the beta-position are termed 2-naphthalene derivatives. There seems to be some irregularity in this system, for an iodo-naphthalene, the structural formula of which shows it to be of the alpha (1) type, is termed "Jodnaphthalin," though it is stated in the text that the process used for its production gives rise to a large amount of the 1-form with a small proportion of the 2-form. Still, it seems to the reviewer to be a mistake to give a structural formula without the strictly systematic name. In the case of naphthalene, the abandonment of the signs alpha and beta, and the substitution of the common numerals is an advantage to author, compositor and reader, and chemists may well say " for this relief much thanks."

It scarcely needs to be added that the book is a most important and valuable contribution to the field of coal-tar chemistry and will be an indispensable guide to all who are engaged in either the practical or theoretical work in the field which, in the advertisement of one of the largest American dye-manufacturing companies, is called the "keystone of American industries." Great economic problems are now before the nations, one of the most important phases being the building up of the coal-tar utilizations, so that each nation may be fairly independent of all others in the productions of dyes, explosives, medicines and the more than a thousand and one other substances which have been obtained from the distillation of crude fuels. Certainly, the United States does not want to be caught again as it was in 1914, without full supplies of all these types of materials. An inspection of this book will show that whatever tariff and license systems may accomplish, an equal cultivation of theory and practice is essential to the establishment of industries that can stand alone and develop independently of other nations, and that in the last analysis of such matters the scientist will regard neither friend nor foe, past, present or possibly future, but will ask merely for trustworthy data and interpretive theories.

HENRY LEFFMANN.

LABORATORY EXPERIMENTS IN ORGANIC CHEMISTRY, DESIGNED ESPECIALLY FOR USE WITH STODDARD'S INTRODUCTION TO ORGANIC CHEMISTRY. By E. P. Cook, A.M., Associate Professor of Chemistry in Smith College. Second edition, small 8vo., 70 pages, contents and index. Philadelphia, P. Blakiston's Son & Co., 1920. $1.00.

The author states that the procedures selected for presentation in this book are such as have seemed, in a large experience, most suitable for a first course in organic chemistry. The time given to the laboratory work in this course at Smith College is four hours per week during a college year. Some processes which require considerable time, are distinguished by an asterisk, that they may be omitted if necessary.

A commendable feature is the omission of all equations, thus leaving to the student the task of determining the nature of the reactions by consulting text-books. The nomenclature used is also to be commended, as it is systematic and correct. It is exasperating to see in modern chemical works or journal articles such expressions as "benzol," "permanganate of potash," "caustic soda." The book is of convenient size and shape, and the text carefully prepared.

HENRY LEFFMANN.

THE HANDBOOK OF INDUSTRIAL OIL ENGINEERING. Lubrication and Industrial Oil Section. By John Rome Battle, B.Sc. in M.E., M.E. Small 8vo., limp cloth, 1065 pages, index and many illustrations, diagrams and specimen sheets. Philadelphia, J. B. Lippincott Co., $10.00.

"Pouring oil on troubled waters" has been for a long while an expression of peace-making, but times are changed and we are changed with them, for today oil is seriously troubling the waters of internationalism. The book in hand does not deal with the economic or diplomatic problems, but with the application of oil to the many varieties of industries. It is impossible in the space available to present more than an outline of its character and contents. It contains a vast amount of information, being encyclopædic in scope, within the field to which it is devoted. It must represent an enormous amount of labor in searching the literature, compiling and condensing data, and last, but not least, the reading of the proof. Though not stated on the title page, the book is a second edition, as indicated by the copyright entries, the first issue having been copyrighted in 1916. Each copy is accompanied by an unstamped card provided for advising the author of errors discovered by those who use the work. This is an excellent plan, and it is to be hoped that the example will be followed, inasmuch as the author promises to communicate to those who notify him of errors a summary of those that have been indicated by others. This method of keeping in touch with one's readers ought to be popular, but an experience along the same line by the present reviewer, who adopted it in a book published by him, showed that but very few availed themselves of the opportunity, for though hundreds of copies of the book have been sold, only a score or so have taken advantage of the opportunity.

As might be expected, the bulk of the book is devoted to the petroleum oils, but about two score pages are given to the fixed oils used in lubrication, which section contains a very large amount of information. In the initial paragraph, the reviewer notes a slight typographic error, the name of the radicle "glyceryl" being spelled "glyceril," but a more serious error is the statement that the radicle of glycerin or glycerol is $(C_3H_5(OH)_3)$. There is some accidental confusion here. It is probable that the author intended to write "formula" instead of "radicle." It is gratifying to see the correct spelling of the word "radicle," so often incorrectly spelled "radical," which is the adjective form.

The work is divided into 11 sections, the limits of which are indicated by thumb-pieces, but while there is a table of contents (placed a little awkwardly on the fly-leaves), there is no summary of the titles of the sections themselves, which seems to be a slight defect.

The descriptive matter is preceded by some elementary mathematics, including methods of arithmetic relating to fractions, and a brief presentation of the principles of logarithms, with a two page table of five-figure logarithms, but it is doubtful if any one who does not understand the use of such a table could gain much from what is there given.

The printing and other mechanical features of the book are excellent, and reflect credit on all concerned. The author's painstaking efforts have resulted in a most valuable compendium in a most important field of industry.

HENRY LEFFMANN.

CHEMISTRY AND CIVILIZATION. By Allerton S. Cushman, A.M., Ph.D., Director, Institute of Industrial Research. Ex-Lieut. Col. Ordnance Dept., U. S. A. Small 8vo., 148 pages, index, six plates and two illustrations in the text. Boston, Richard G. Badger. $2.50 net.

Doctor Cushman delivered the 1920 course of lectures with the above title at the Wagner Free Institute of Science, under the Richard B. Westbrook Foundation, and has presented the substance of the course with numerous additions in the book in hand. It is a very valuable and interesting essay. English-speaking chemists are now actively engaged in bringing to the notice of the mass of the people the value of both pure and applied chemistry, and Doctor Cushman's book will be no small aid in the propaganda. Beginning with a summary of the development of the science from its earliest period to the establishment of accurate methods of procedure, the author passes to the service of the science to the human race, starting with the researches of the early nineteenth century, certain distinguished leaders being especially noted. The application of chemistry to industry is then taken up, several of the key industries being noted, namely, the alkali industry (Leblanc to Solvay), sulphuric acid, the Bessemer and Siemens-Martin processes, the discovery of benzene and the introduction by Kekulé of the benzene-ring theory, with the subsequent extensive and valuable development of synthetic chemistry.

"Chemistry and War," the subject matter of the fourth chapter, covers the topics of nitrogen fixation, coal-tar industries, poison gases and gas masks, sources of potash and chemical developments in military surgery. Concerning the first topic, one of the most important problems in applied chemistry, the book gives a concise and highly informing account. A footnote describes in some detail the work accomplished by German chemists at the plant of the BASF during the war. In this connection attention may be called to the fact that in the Emil Fischer memorial address before the (British) Chemical Society, the speaker stated that if the Germans had not had available the Haber process for utilization of atmospheric nitrogen, the war would have closed in the summer of 1915, for the British blockade would have prevented the Central Empire from getting supplies of Chili nitrate. Doctor Cushman points the moral of this fact in its relation to the development of the nitrogen fixation industries in the country, and his book will render most valuable service in this regard.

A chapter on "Chemistry and the Future" presents interesting data in regard to radio-activity and, of course, the author wrestles a little with the Einstein theory.

The last chapter discusses some of the modern aspects of chemistry, including colloids, the future of alcohol, chemical actions at high and low temperatures and pressures, the low motor-fuel problem and the story of helium. The last item naturally leads the reviewer to examine if the author has been caught in the bewitchment of the bibliography of this element, and finds it stated that Lockyer and Janssen had mapped the yellow line of the element in the sun in 1865, and had called it helium. The now famous eclipse occurred in 1868, and there is no evidence that Janssen had any share in coining the name, at least, Lockyer said in 1894, that he coined the name for "laboratory purposes."

Dr. Cushman's book deserves to be widely read among the intelligent members of the community who though not trained in chemistry are interested in the devlopments of our chemical industries. The literary style is excellent. The reviewer is glad to see that the American spelling of chemical terms is adopted.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE ON AERONAUTICS.

Report No. 94. The efficiency of small bearings in instruments of the type used in aircraft by F. H. Norton, aerodynamical laboratory, National Advisory Committee for Aeronautics, Langley Field, Va. 10 pages, illustrations, plates, quarto. Washington, Government Printing Office, 1920. This report deals with the construction and properties of bearings and pivots for use in instruments. The static and running friction for both thrust and radial loads was determined for a number of conical pivots and cylindrical and ball bearings. The static rocking friction was also measured for several conical and ball bearings under a heavy load, especially to determine their suitability for use in an N. P. L. type wind tunnel balance. In constructing conical pivots and sockets it was found that the pivots should be hardened and highly polished, preferably with a revolving lap, and that the sockets should be made by punching with a hardened and polished punch. It was found that for a light load the conical pivots give less friction than any other type and their wearing qualities when hardened are excellent. When the load exceeds about 1000 grams ball bearings give less friction than pivots and will stand shocks and wear better. Very small ball bearings are unsatisfactory because the proportional accuracy of the balls and races is not high enough to insure smooth running. For rocking pivots under heavy loads it was found that a ball and socket bearing, consisting of a hemispherical socket and a sphere of smaller diameter concentric with it with a row of small balls resting between the two was superior to a pivot resting in a socket. It was found that vibration such as occurs in an airplane will greatly reduce the static friction of a pivot or bearing, in some cases to as little as one-twentieth of its static value.

PUBLICATIONS RECEIVED.

National Advisory Committee for Aeronautics: Fifth annual report, 1919. 870 pages, illustrations plates, diagrams, quarto. Washington, Government Printing Office, 1920. Sixth annual report, 1920. 56 pages, quarto. Washington, Government Printing Office, 1920. Technical Notes, No. 17, Italian and French experiments on wind tunnels, by Wm. Knight, 8 pages, plates, quarto. Technical Notes, No. 19. The steadiness factor in engine sets, by W. Margoulis, aerodynamical expert. Paris Office, N.A.C.A. 10 pages, plates, quarto. Technical Notes, No. 24. Development of the inflow theory of the propeller, by A. Betz. Résumé translated from the German, by Paris Office, N.A.C.A. 4 pages, plates, quarto. Technical Notes, No. 27. Instrument for measuring engine clearance volumes, by S. W. Sparrow, automotive power plants section, Bureau of Standards. 4 pages, plates quarto.

U. S. Weather Bureau: Daily river stages at river gage stations on the principal rivers of the United States. Vol. 17, for the year 1919, by Alfred J. Henry, meteorologist. 291 pages, quarto. Washington, Government Printing Office, 1920.

U. S. Bureau of Mines: Monthly statement of coal mine fatalities in the United States August and September, 1920, by W. W. Adams, 2 pamphlets. 8vo. Washington, Government Printing Office, 1920.

Catalysis in the Hydrolysis of Esters by Infra-red Radiation.—ERIC K. RIDEAL and JAMES A. HAWKINS (*Jour. the Chem. Soc.*, 1920, cxvii, 1288–1296) find that the hydrolysis of methyl acetate by dilute hydrochloric acid is catalytically accelerated by infrared radiation. The temperature of the mixture of ester and dilute acid was kept constant by means of a thermostat. In the experiment proper the mixture was subjected to infra-red radiation usually obtained from sunlight or from a glowing Nernst filament by means of an optical system of lenses and a quartz prism. In the control experiment the mixture was not illuminated. In a series of such experiments the illuminated ester was hydrolyzed far more rapidly than the ester which was kept at the same temperature in the dark.

J. S. H.

Amino Acids of Gelatin.—The amino acids which occur in the protein gelatin have been separated and determined by H. D. DAKIN (*Jour. of Biol. Chem.*, 1920, xliv, 499–529). The per cent. of each amino acid found was: Glycine, 25.5; alanine, 8.7; leucine, 7.1; serine, 0.4; phenylalanine, 1.4; tyrosine, 0.01; proline, 9.5; hydroxyproline, 14.1; aspartic acid, 3.4; glutamic acid, 5.8; histidine, 0.9; arginine, 8.2; lysine, 5.9; ammonia, 0.4. The sum of these ingredients amounts to 91.31 per cent., while previous analysts have accounted for considerably less of the total amino acid content of the gelatin, their sums ranging from 42.1 to 70.7 per cent. out of the total 100 per cent. It is noteworthy that traces of tyrosine were always found, although this amino acid hitherto has been considered absent from the gelatin molecule. The following amino acids were not present in gelatin: Valine, isoleucine, aminobutyric acid, and hydroxyglutamic acid. Unidentified sulphur derivatives were also found in the gelatin molecule. Since isoleucine and valine are absent, and considerable leucine is present, gelatin is a very suitable material for the preparation of optically pure leucine.

J. S. H.

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Devoted to Science and the Mechanic Arts

Vol. 191 FEBRUARY, 1921 No. 2

HELIUM: ITS HISTORY, PROPERTIES, AND COMMERCIAL DEVELOPMENT.*

BY

RICHARD B. MOORE, B.S., D.Sc.

Chief Chemist, U. S. Bureau of Mines.

THE story of Helium is one of the romances of science. There is probably nothing, unless it be the story of radium, which can compete with it in human interest. It represents one of the very best examples of a discovery in pure science which ultimately has a great commercial application.

In 1868 there was an eclipse of the sun which was visible in India. A number of scientific men were in India at the time making observations of the eclipse, and a spectroscope was for the first time turned on the solar chromosphere, that portion of the atmosphere of the sun, about ten miles deep, which merges into the corona. A bright yellow line was observed which was at first thought to be the sodium line. Janssen,[1] however, showed that this line was not exactly the same as the D_1 and D_2 lines of sodium, although extremely close to these lines. He, therefore, suggested that the line have the designation D_3. Frankland and

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* Presented at a joint meeting of the Section of Physics and Chemistry and the Philadelphia Section of the American Chemical Society held Thursday, February 5, 1920, and published by permission of the Director of the Bureau of Mines.

[1] Janssen: *Compt. rend.*, 1868, 67, 838.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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Lockyer[2] decided that this line was due to a new element in the sun which had not previously been discovered on the earth and they suggested the name "Helium," from the Greek word "Helios," meaning the sun.

For a great many years nothing more was done in connection with this element. In 1888, Dr. W. F. Hillebrand,[3] of the United States Geological Survey, examined the gases which were evolved from certain uraninites when boiled with dilute sulphuric acid. Hillebrand obtained an inert gas which showed all of the properties of nitrogen. When sparked with hydrogen, in presence of hydrochloric acid, it gave ammonium chloride, and when sparked with oxygen, it gave oxides of nitrogen. The spectrum also was that of nitrogen. On the other hand, it was noticed that there were some lines in this spectrum which did not belong to nitrogen, and, in addition, after continuous sparking for a considerable period, there was a residue which diminished in volume very slowly. It is a great pity that American science was not responsible for the discovery of terrestrial helium. On the other hand, those who have worked with the rare gases can fully appreciate the difficulties attendant on work of this kind before the necessary technic was even partially developed.

In 1894, Sir William Ramsay, in conjunction with Lord Rayleigh,[4] made his memorable discovery of argon in the atmosphere, which discovery was announced at the British Association Meeting in the same year. After this discovery, Ramsay looked for other sources of the element. He heard through Sir Henry Miers of the observation of Doctor Hillebrand, described above, and suspected that the inert gas found by Hillebrand might be argon. He obtained a sample of the mineral clevite from Doctor Hillebrand, placed it in a tube connected with a Töpler pump, heated the mineral with sulphuric acid, pumped off the evolved gas, sparked the latter with oxygen, removed the excess of oxygen, and finally ran the purfied gas into a spectrum tube. The spectrum was entirely different from that of argon, having as a chief characteristic a bright yellow line. Sir William once described to the writer, in his characteristic manner, his surprise at what he saw when he put his small spectroscope to his eye. He was expecting to see the argon spectrum, consisting of lines more or less evenly distributed across the whole field of the instrument, or at least the bands of nitrogen. Instead, he observed a very brilliant yellow line, with two or three fainter reds, as many greens, and as many violets. These were more or less masked by slight impurities in the gas. His surprise was so great that he thought at first there was something wrong with his spectroscope, and took out his handkerchief and mechanically wiped the prism. Others were called in who suggested various explanations for the bright yellow line, the most common being that it was the sodium line due to dirty electrodes or other causes. It was only when the spectrum of the sodium flame was compared with the yellow line from the spectrum tube that it became evident, and beyond question, that a new element—terrestrial helium—had been discovered.[5] The wave-length was measured by Sir William Crookes,[6] and proved to coincide with that of the D_3 solar line.

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[2] Frankland and Lockyer: *Proc. Roy. Soc.*, 1868, **17**, p. 91.

[3] Hillebrand, W. F.: On the Occurrence of Nitrogen in Uraninite, *U. S. Geol. Survey Bull.* 78, 1891, pp. 43–79.

[4] *Proc. Roy. Soc.*, **58**, pp. 65–81, 1895. *Chem. News*, **71**, p. 151, 1895.

As would be natural under such circumstances, it was not long before the work had its critics, and the elemental character of the gas was attacked. Runge and Paschen [7] showed that if the gas was allowed to pass through a porous plug, and from thence into an evacuated spectrum tube, the light at first obtained was greenish, afterwards gradually becoming yellow. At the same time, the intensity of the D_3 line increased. From this they thought that two gases were probably present, and by means of diffusion they had made at least a partial separation. This claim received some support from the fact that the density of helium obtained from minerals was not always constant, and varied within moderate limits. If helium from this source was allowed to diffuse through porous earthenware, fractions of different densities could be obtained.

Travers [8] proved that the difference of color in the spectrum was due to the difference in pressure in the tube. At extremely low pressures, the light given out was greenish in color, but as the pressure increased, the color became yellow and even orange yellow. In addition, Ramsay and Travers[9] showed that by fractional diffusion helium from minerals could be separated into fractions of different density, but that these differences were due to traces of argon, which gas also was obtained from the minerals, in small quantity, mixed with the helium.

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[5] Ramsay, Wm.: Discovery of Helium in Clevite, *Jour. Chem. Soc.*, 67, 1107.

[6] Crookes, Wm.: *Proc. Roy. Soc.*, 58, 69, 1895.

[7] Runge and Paschen: *Phil. Mag.*, 1895 (v.), 40, 297.

[8] Travers: *Proc. Roy. Soc.*, 1897, 60, 449.

The presence of helium in the atmosphere was first discovered by Kayser[10] in 1895, and was confirmed by Friedlander.[11] Later the gas was shown to be a constituent of the gases evolved from numerous mineral springs and was also found in volcanic gases, and ultimately in certain natural gases, particularly in the United States.

The discovery of argon, followed by the discovery of helium, was the forerunner of the series of brilliant researches by Ramsay and Travers, which gave to the world five new elements, commonly called rare gases of the atmosphere, namely, helium, neon, argon, krypton, and xenon.

OCCURRENCE.

Helium, as already stated, is found in the atmosphere. Ramsay's first determination of the proportion was one part in 245,000 by volume. Watson,[12] using rather better methods, found what is probably a more accurate figure, namely, one volume in 185,000.

Samples of air at an altitude of several miles have been collected and analyzed for rare gases, and the percentage of helium found has always been approximately the normal one. J. H. Jeans[13] has done some theorizing on the proportion of helium in the atmosphere at different altitudes. His theory is that the atmosphere consists of more or less concentric layers containing different proportions of constituents. The proportion of helium does not vary materially unless a considerable altitude is attained, such as fifty miles, at which point the air consists mainly of nitrogen and hydrogen, with three times as much helium as oxygen. At 100 miles the atmosphere is principally hydrogen and helium, and at 500 miles it consists entirely of hydrogen and helium.

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[9] Ramsay and Travers: *Proc. Roy. Soc.*, 1897, **60**, 206.

[10] Kayser: *Chem. News*, 1895, **72**, 89.

[11] Friedlander: *Zeitsch physikal Chem.*, 1896, **19**, 657.

[12] Watson: *Trans. Chem. Soc.*, 1910, **97**, 810.

[13] Jeans, J. H.: "The Dynamical Theory of Gases," chap. 15. Cambridge, 1916.

On this theory, a calculation of the total mass of helium in the atmosphere gives eleven billion tons.

Others do not agree with this theory. Dr. Johnstone Stoney[14] claims that the helium cannot be retained permanently by a planet of the size of our earth as the gas must be continually thrown off into space. The presence of helium in the atmosphere in constant proportions, therefore, depends upon a steady source of supply to make up the loss. Stoney's conclusion is supported by both Ramsay and Moureu.

Helium is found in very minute quantities in sea and river water, and in a large number of the older rocks and minerals. It undoubtedly exists in some of the fixed stars as well as in the sun, and its presence has been spectroscopically determined in many nebulæ.

Helium is found in the gases evolved from a large number of mineral springs. Moureu and Lepape[15] have done a considerable amount of work on determining the presence of the rare gases in gases evolved from mineral springs in France. Some springs give off gases containing a very considerable proportion of helium, that at Mazières containing over 5 per cent. of the rare gas and two springs at Santenay more than 8 per cent.

Locality.	Spring.	Nitrogen.	Argon.	Helium.
Aix-les-Bains	Alun		1.153	.037
Badgastein, Austria	Gratenbüker	97.25	1.181	.169
Bagnères-de-Luchon	Bordeu No. 2	96.45	1.25	.15
Bagnères-de-Luchon	Ferras	96.085	1.23	.285
Bagnères-de-Luchon	Saul No. 2	94.826	1.271	.323
Bourbon-Lancy	Lymbe	91.96	1.20	1.84
Bourbon-Lancy	Reine	96.1	1.15	1.75
Cauterets	César	98.55	1.275	.165
Cauterets	Raillère	98.508	1.377	.115
Grisy	Ys	95.5	1.18	2.18
Mazières	Romaine	91.46	.92	5.92
Nancy	Parc Sainte-Marie	95.36	1.29	1.60
Plombières	No. 3	94.505	1.375	.120
Plombières	No. 5	95.32	1.547	.104
St. Honoré	Crevasse	95.76	1.147	.893
Santenay (Cote d'Or)	Carnot			9.76
Santenay (Cote d'Or)	Fontaine Slaee			8.40
Uriaae		93.98	.938	.932

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[14] *Chem. News*, 1895, **71**, 67.

[15] *Comp. rend.*, 1895, **121**, 819; 1904, **139**, 852; 1906, **142**, 1155; 1911, **153**, 740; 1911, **152**, 935. Moureu and Biquard: *Compt. rend.*, 1906, **143**, 795; 1908, **146**, 435.

In addition, the gases from the Bath Spring[16] in England are particularly rich in helium, and also carry as much as .24 parts of neon per 100 parts of nitrogen in the gas.

Very little work has been done along these lines in connection with springs in the United States. Recently, however, the Bureau of Mines has tested the gases evolved by a number of the geysers and hot springs in Yellowstone Park; for example, the Excelsior geyser, the Handkerchief pool, the pool near the north of Fountain Inn, a pool northeast of the Lion geyser, a pool near the Constant geyser in Norris basin, a muddy pool giving off sulphur dioxide close to the Monarch geyser, and a number of others. In no case was helium found in quantities sufficient to determine quantitatively in the sample taken. The actual volumes of helium evolved by some of the springs in France are quite large. Moureu and Lepape[17] have calculated some of these volumes and they have shown that the following volumes in cubic feet are evolved each year by the springs mentioned:

Santenay (Cote d'Or)	183
Neris (Allier)	1200
Bourbon-Lancy (Saone et Loire)	356
La Bourboule (Puy-de-Dôme)	108

Helium is found in certain volcanic and fumarole gases. The presence of the rare gas in Italian fumarole gases was determined as far back as 1898 by Nasini.[18]

The boracic acid fumaroles of Ladarello give off largely steam, the steam being used for generating power. The rest of the gas is carbon dioxide, with traces of hydrogen, methane, hydrogen sulphide, nitrogen, etc. The original analysis of Nasini showed something more than 90 per cent. carbon dioxide in the gas after the steam was condensed and from ten hundredths to fifteen hundredths of one per cent. helium.

Thorkelesson[19] examined gases from certain hot springs in Iceland. The analyses showed from .0006 to .0104 per cent. helium. The nitrogen content was high in many of the gases, some containing as much as 95 per cent. nitrogen. The percentage of argon was much higher than that of helium, namely from .01 to 1.93 per cent.

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[16] Ramsay, Wm.: Report on the Mineral Waters of Bath, *Chem. News*. Vol. 105, 1912.

[17] *Compt. rend,* 155, 1912.

[18] Nasini, Anderlini, and Salvadori: *Gazz. chim. ital.*, Vol. 28, 1898, pp. 81–153. *Idem.*, Vol. 36, pt. 1, 1906, p. 429.

[19] Thorkelsson: *Danemark Mem.*, 7th Ser., Vol. 8, 1910, pp. 181–264.

R. J. Strutt first systematically took up the investigation of the helium content of rocks and minerals. The helium cannot be determined directly in an igneous rock on account of the minute quantity present, but if it is assumed, as is probably the case, that the helium present is due to radioactive changes, if the radium present in the rock is determined, at least some very rough estimate of the probable helium content may be obtained. In the case of minerals containing thorium and uranium, the matter is very different, as the helium present can be actually measured quantitatively. This can be done in the following manner: If the mineral is soluble in sulphuric acid, a weighed quantity is placed in a heavy glass tube connected with a Töpler pump, and an arrangement made so that a sufficient amount of sulphuric acid can be introduced into the tube when desired without introducing air. The whole apparatus is exhausted and the acid brought in contact with the mineral. After complete solution and heating, the evolved gases are pumped off into a test tube over mercury. This gas is then sparked for several hours with some pure oxygen in presence of a small amount of strong caustic soda solution. This gets rid of all traces of nitrogen, the oxides formed being dissolved by the caustic soda. The partially purified gas is then run into another test tube over mercury and the oxygen removed by a globule of melted phosphorus. The phosphorus not only removes the oxygen, but the phosphorus pentoxide formed in the reaction dries the gas. This gas is then run into a burette and measured. Such a result gives the total amount of rare gas present which, in the case of minerals, is almost entirely helium. Some small traces of argon, however, are at times present. If desired, the argon can be removed by means of charcoal at the temperature of liquid air, and the helium pumped off can be remeasured.

If the mineral is not soluble in acid, the helium may be liberated by fusion with fusion mixture. Otherwise, the treatment is the same. A certain proportion of the helium in a mineral can also be obtained by heating the mineral direct without any chemical treatment. On heating monazite to 500° C. only a very small percentage of the helium is evolved. At 900° C., 24 hours heating is required to liberate all of the gas. For thorianite, 7 per cent. is obtained at 300° C. after 5 hours heating, 8.5 per cent. at 500° C. after 80 hours, and the whole at 1000° C. after 30 hours. Usually helium is only found in measurable quantity in those minerals which contain thorium or uranium, such as carnotite, thorianite, pitch blende, etc.[20]

One mineral, beryl, has been found to contain a considerable amount of helium, and practically no radioactive matter from which the helium is supposed to be derived. Boltwood explains this on the basis that in the crystallization of the mineral only one of the shorter lived products of disintegration, such as radium or ionium, has remained with the mineral. This has decayed with the formation of helium, and as there was no uranium or thorium present, the mineral became inactive. This explanation, however, assumes no other possible origin for the helium than radioactive matter. Piutti[21] has found similar occurrences.

The volume of helium contained in any mineral depends upon several factors such as its geological age, the percentage of thorium or uranium present, and the density of the mineral which will largely control the leakage of the helium from the crystals.

The following table gives approximate volumes of helium which can be obtained from different minerals.

Mineral.	Observer.	Helium in c.c. for 1 gram of Mineral.
Clevite	Ramsay	7.2
Fergusonite	Ramsay	1.1
Fergusonite	Travers	1.813
Samarskite	Ramsay and Travers	1.5
Monazite	Strutt	2.41
Pitchblende	Ramsay and Travers	.30
	Strutt	.107
Thorianite	Buchner	8.2
	Strutt	8.9

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[20] Ramsay: *Proc. Roy. Soc.*, 1896, **59**, 325. Ramsay and Travers: *Ibid.*, **60**, 442. Ramsay, Collie, and Travers: *Trans. Chem. Soc.*, 1895, **67**, 689. Olzewski: *Bull. Acad. Sci. Cracow*, 1905, p. 407. Bordas: *Compt. rend.*, 1908, 146, 896. Waters: *Phil. Mag.*, 1909 (vi.), **18**, 677; **19**, 903. Thomsen: *Zeitsch. physikal Chem.*, 1898, **25**, 112. Benedicks: *Bull. Geol. Inst. Univ. Upsala*, 1899, **4**, 1. Lange: *Zeitsch. Naturwiss.*, 1910, **82**, 1. Tschernik: *J. Russ. Chem. Soc.*, 1897, **29**, 291. Kitchin and Winterson: *Trans. Chem. Soc.*, 1906, **89**, 1570. Strutt: *Proc. Roy. Soc.*, 1908, A, **81**, 278. Hogley: *Phil. Mag.*, 1909 (vi.), **18**, 672. Piutti: *Le Radium*, 1910, **7**, 146. Strutt: *Proc. Roy. Soc.* (a), **76**, 1908, 80; *Ibid.* (A), **80**, 1908, 56. *Chem. News*, 1909, 99, 145, and many others.

[21] Piutti: *Le Radium*, **7**, 1910, 178. *Chem. Abs.*, **4**, 1910, 3055.

Strutt[22] has examined the saline minerals of Stassfurt and found not only that they contain helium in appreciable quantities, but also that the percentage of helium was very many times larger than could be justified by the uranium content of the mineral. The following table gives in a concrete form some of the results obtained:

Mineral.	Composition.	Helium, c.mm. per 100 grammes.	Grammes uranium oxide (U_3O_8) per 100 grammes.	Helium, c.c. per gramme U_3O_8.
Rock Salt..........	$NaCl$	0.0233	7.1×10^{-6}	3.3
Sylvine............	KCl	0.55	2.15×10^{-6}	256
Carnallite.........	$KMgCl_3 6H_2O$	0.151	3.23×10^{-6}	47
Kieserite..........	$MgSO_4H_2O$	0.0179	6.47×10^{-5}	0.277

The following were also examined: kainite, krugite, astrakanite, längbeinite, polyhalite, schoenite, and tachydrite, and in none of these was the quantity of helium at all comparable with what was observed in carnallite or sylvine, but the D_3 line could nearly always be seen. Strutt stated that it was altogether improbable that the minute quantities of uranium and radium present could account for the helium content in the carnallite and sylvine. On the other hand, the helium in the rock salt was much of the order that could be expected from its geological age if the helium originated from the radioactive material present.

In 1907 Cady and McFarland[23] published a report on the presence of helium in a number of natural gases, mainly from Kansas. Some of the samples tested ran as high as 1½ per cent. helium by volume. The list on page 154 represents a selected number from results obtained by these authors.

It was pointed out that there seemed to be a distinct connection between the nitrogen and helium present, as in many cases the helium was in rough proportion to the nitrogen. It was the results of Cady and McFarland, on the natural gases of Kansas, that formed the foundation for the belief that an adequate supply of helium could be obtained from natural gas in the United States for use in balloons and dirigibles.

C. W. Seibel[24] has shown that not only is helium present in

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[22] Strutt: *Roy. Soc. Proc.,* A, Vol. 80, 1908, p. 572. *Ibid.,* A, Vol, 81, 1908, p. 278.

[23] *Jour. Amer. Chem. Soc.,* 1907, 29, 1524.

[24] *Met. and Chem. Eng.,* May, 1917.

Composition of Natural Gases.

No. Locality.	Oxygen O_2	Carbon Dioxide CO_2	Olefines C_2H_4	Carbon Monoxide CO	Methane CH_4	Ethane C_2H_6	Hydrogen H_2	Helium He	Nitrogen N_2
1 Dexter, Kansas..........	0.20	.00	.....	.00	14.85	.41	trace	1.84	82.70
6 Dexter (Greenwell well), Kansas................	.10	.00	.00	.00	14.33	1.06	trace	1.64	82.87
41 Eureka new well, Kansas.	.10	.20	.00	.00	51.80	.00	.00	1.50	46.40
9 Fredonia, Kansas.......	trace	.61	.12	.00	82.25	.00	.00	.616	16.40
4 Eudora, Kansas.........	.31	.62	.00	.00	88.60	.00	.00	.27	10.20
37 Augusta, Kansas........	.00	.00	.77	.00	79.10	7.44	.00	.25	12.44
20 Moran, Kansas.........	.20	.30	.35	.20	92.00	.00	.39	.214	6.35
24 Butler, Ohio............	.05	.00	.40	.00	70.00	16.75	.27	.15	12.38

these natural gases, but also small quantities of the other rare elements, even krypton and xenon.

Moureu and Lepape [25] and Voller and Walter [26] have pointed out that very small quantities of helium are contained in certain natural gases in Europe, but the quantities are extremely small and the occurrences unimportant.

PROPERTIES.

Up to the present, no one has succeeded in combining helium with any other element or getting the gas to take part in a chemical reaction under any conditions whatever. In this respect it is similar to argon and the other rare gases. Shortly after helium was discovered Ramsay and Collie [27] carried out an exhaustive series of experiments in order to test the chemical inertness of the gas. A definite volume of helium was passed over a series of substances heated to a bright red heat. The helium was finally pumped off and measured, and the substance used was reheated, and any evolved gas was collected and measured. In no case was there any change in the volume of the helium, and in every instance the other substance was apparently unaffected. Sodium, phosphorus, zinc, cadmium, and arsenic were all distilled in the gas, and the following substances were also strongly heated: glucinum, silicon, boron, magnesium, thallium, titanium oxide and magnesium, thorium oxide and magnesium, sulphur, selenium, antimony, bismuth, metallic cobalt, platinum black, soda lime and potassium nitrate, and soda lime and sulphur. The gas has also been sparked, and strongly heated with all other known gases without result.

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[25] *Compt. rend.*, **155**, pp. 197–200, 1912.

[26] *Hamburger Wiss. Inst.*, **28**, 1910.

[27] *Proc. Roy. Soc.*, 1896, **60**, 53.

Sieverts and Bergner [28] have shown that helium is not soluble in certain solid or liquid metals, such as gold, nickel, silver, copper, iron, palladium, uranium, aluminium, magnesium, etc.

If fergusonite is heated to 600° C. it suddenly begins to glow, and the gas which is evolved consists very largely of helium, namely between 70 and 80 per cent. The heat evolved is considerable, being more than 800 cal. per gram of mineral. This might indicate that helium was held in the mineral in combination. On the other hand, it has been pointed out by Travers [29] that a similar phenomenon sometimes occurs with minerals which do not contain helium. An examination of the rate of production of helium from minerals, both by means of heating, and by fine grinding *in vacuo,* seems to indicate that the helium is contained in the mineral in very minute cavities, and not in actual combination.

It has been suggested that the splashing of the electrode metal observed on the side of a Geissler tube containing helium and the other rare gases is due to an endothermic compound. There is, however, no definite proof of such an assertion.

Solubility.—Antropoff [30] has determined the solubility of helium in water. He obtained the following results for the absorption coefficient: 0° C.–.0134, 10° C.–.0100, 20° C.–.0139, 30° C.–.0161, 40° C.–.0191, 50° C.–.0226. More recent results,[31] obtained by Antropoff, gave the following corrected values: 0° C.–.00967, 10° C.–.00991, 20° C.–.00996, 30° C.–.01007, 40° C.–.01029, 50° C.–.0108. The existence of a minimum is not unusual, as it is found in the case of other inert gases, and also hydrogen.

Thermal Conductivity.—The thermal conductivity of helium has been studied by Schwarze.[32] If, in the equation $K = f.n.c_v$, n and c_v are the viscosity and the specific heat at constant volume respectively, and f is a constant, then K is the thermal conductivity of the gas for helium. At 0° C., K was found by Schwarze to be .0003386.

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[28] *Ber.,* 1912, 45, 2576.

[29] *Nature,* 1905, 71, 248.

[30] *Proc. Roy. Soc.,* 1910, A, 83, 474.

[31] *Zeitsch. Elektrochem.,* 1919, 25, 269–297.

[32] *Physik. Zeit.,* 4, p. 229; 1903. *Ann. Physik.* (4), 11, pp. 303–330, 1903.

Viscosity.—Schultze[33] found that the viscosity of helium at 15° is 1.086 times the viscosity of air. Rankine[34] later repeated the work using different apparatus, and confirmed Schultze's figure.

If the absolute value for the viscosity of air is taken at 15.5° C., and is $n = 1.803 \times 10^{-4}$ $C.G.S.$ units, then the viscosity of helium at 15° is 1.958×10^{-4} $C.G.S.$ units.

Density.—The density of helium has been determined by a number of observers. The following results have been obtained (oxygen = 16): 1.979,[35] 2.00,[36] 1.99,[37] 1.995,[38] 1.999.[39] It is probable that the determination of Watson of 1.995 is as accurate, if not more so, than any of the others.

The atomic weight and molecular weight of helium are, of course, the same since the gas is monatomic, and the figure 4 is generally accepted. A recent determination by T. S. Taylor[40] gives the weight of a normal liter of helium (oxygen = 16) as 0.17850 ± 0.000015. The molecular weight (oxygen = 32) is 4.0008 ± 0.0005.

Dielectric Cohesion.—Helium conducts a current better than any known gas except neon. The dielectric cohesion of helium is 18.3, air being 419, argon 38, and neon 5.6.[41] This property of helium is readily illustrated by means of a tube containing movable electrodes in which certain gases can be introduced, and held at definite pressures. With the same difference of potential, pressure, etc., oxygen gave a spark of 23 mm.; hydrogen, 39 mm.; argon, 45.5 mm.; and helium 250 mm.[42]

Refractivity.—This property of helium was first determined by Rayleigh, but his figures were not correct. Ramsay and Travers [43] repeated the measurements and determined the refractivity of helium ($\mu - 1$) to be 0.1238 times that of air which gives the value of μ as 1.0000361. Other observers [44] have obtained slightly lower figures than Ramsay and Travers.

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[33] *Ann. Physik.*, 1901 (iv), **6**, 302.

[34] *Proc. Roy. Soc.*, 1910, A, **83**, 265.

[35] Ramsay and Travers: *Proc. Roy. Soc.*, 1898, **62**, 316.

[36] Olszewski: *Ann. Physik*, 1905 (iv), **17**, 997.

[37] Onnes: *Comm. Phys. Lab. Leyden*, 1908, No. **108**.

[38] Watson: *Trans. Chem. Soc.*, 1910, **97**, 810.

[39] Heuse: *Ber. deut. physikal Ges.*, 1913, **15**, 518.

[40] *Phys. Rev.*, **10**, 653–60 (1917).

[41] Bouty: *Compt. rend.*, 1907, **145**, 225. *Ann. Chim. Phys.*, 1911 (viii), **23**, 5; 1913 (viii), **28**, 545.

[42] Collie and Ramsay: *Proc. Roy. Soc.*, 1895, **59**, 257.

Ratio of Specific Heats.—The ratio of specific heats at constant volume has been determined by a number of observers theoretically. This ratio for a monatomic gas should be 1.667. Ramsay found 1.652, and Scheel and Heuse [45] found 1.660 at 18° and 1.673 at −180°.

Specific Heat.—Cp equals 1.2662 ± 0.0011. This figure was determined by Ramsay and Rudorf [46] after carefully taking the weighted averages of the different determinations on the specific heat of the gas. The molecular heat MCp at 18°, according to Scheel and Heuse, is 4.993, and at −180° is 4.934.

Isotopes.—According to J. J. Thomson and F. W. Aston,[47] helium has no isotopes, as shown by the positive ray method of Thomson. This is in contradistinction to neon, which has two isotopes of mass 20 and 22, respectively, and a third doubtful one of mass 31. According to these authors, argon has two isotopes, krypton six, and xenon five.

Spectrum.—Travers [48] found that the color of the discharge through a vacuum tube containing helium depended upon the pressure of the gas, and that the following colors were observed as the pressure got less and less: orange, yellow, bright yellow, greenish yellow, and green. Runge and Paschen [49] found that the spectrum of helium contained six series of lines which fall into two groups, each group consisting of a special series and two secondary series. The first group consists of doublet series and the doublet D_3 is the principal line of this group. It is the lines of this group that are commonly seen in a spectrum tube when the tube is emitting yellow light and the lines of this group are also the ones seen in the chromosphere of the sum. The chief line of the second group has the wave-length 5015.73 in the green, and the lines of this group become more prominent at a lower vacuum when the light emitted from the tube is greenish or yellowish green. The wave-lengths of the D_3 doublet are given by Runge and Paschen as 5876.21 and 5875.88. The measurements of some of the principal lines by different authors are given below:

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[43] *Proc. Roy. Soc.*, 1901, **67**, 331.

[44] Scheel and Schmidt: *Ber. deut. physikal. Ges.*, 1908, 6, 207. Burton: *Proc. Roy. Soc.*, 1908, A, **80**, 390.

[45] Sitzungsber, K.: *Akad. Wiss.*, Berlin, 1913, p. 44.

[46] Ramsay and Rudorf: "Oswald-Drueker," Vol. 11, p. 121.

[47] *Phil. Mag.*, **39**, 611–25, 1920.

[48] *Proc. Roy. Soc.*, 1897, **60**, 449.

[49] *Phil. Mag.*, 1895 (v), **40**, 297.

Runge and Paschen.	Rayleigh I.	Rayleigh II.	Eversheim.
7065.48	7065.192	7065.200	7065.207
6678.37	6678.147	6678.150	6678.151
5875.870	5875.618	5875.625	5875.639
5015.732	5015.682	5015.680	5015.683
4922.096	4921.927	4921.930	4921.934
4713.252	4713.079	4713.144	4713.154
4471.646	4471.480	4471.482	4471.493

Lyman[50] calls attention to a new helium series in the extreme ultra-violet. With a powerful disruptive discharge, a sharp, fairly strong line appears at 1640.2. No trace of this line is found in hydrogen under the same electrical condition, and it does not occur in helium when the discharge circuit is free from capacity. Under the same violently disruptive condition, the line at 1216, always present in helium and hydrogen, develops a satellite on its more refrangible side, of apparent wave-length 1215.1.

Liquefaction of Helium.—Hydrogen on expansion through a nozzle becomes warmer instead of cooler. If hydrogen, however, is cooled by liquid nitrogen boiling under reduced pressure the value of K with the Joule-Thomson effect changes sign, and hydrogen, therefore, can be cooled and liquefied by nozzle expansion. The same condition exists for helium. This gas has to be cooled by liquid hydrogen boiling under reduced pressure to a temperature of 15° C. absolute before expansion in order to produce liquefaction.

Helium was first liquefied by Professor Onnes[51] of the University of Leiden, in 1908, using the method described above. About 60 cubic centimetres of liquid were finally obtained and with this the physical constants of the gas were determined.

A very considerable quantity of the gas which Onnes used was supplied to him by Dr. H. S. Miner, of the Welsbach Company, who has always been generous in assistance of this character to scientific research. A few months ago Professor Onnes was supplied by the U. S. Government with 800 cubic feet of helium obtained at the Texas plants. This material will give Onnes ample opportunity to extend his researches in connection with liquid helium.

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[50] *Science*, November 21, 1919.

[51] *Proc. K. Akad. Wetensch*, Amsterdam, 1908, 11, 168. *Compt. rend.*, 1908, **147**, 421.

Liquid helium is mobile and colorless. Its density determined at different temperatures is as follows:

D.	T. abs.
.1208	4.33
.1216	4.29
.1275	3.98
.1393	3.26
.1459	2.40[52]

Next to liquid hydrogen, it is the lightest liquid known. Its maximum density is at 2.2° absolute. The calculated refractive index is 1.03. The surface tension is small, and the boiling point is 4.25° absolute. The critical temperature is 5.25° absolute, and the critical pressure 2.26 atmospheres. Solid helium has not yet been obtained.

RELATION OF HELIUM TO RADIOACTIVE CHANGES.

Radium, when associated with its disintegration products, gives off three types of rays: alpha, beta, and gamma. The first travels twenty thousand miles a second, and has low penetrating power, being stopped by a thin sheet of paper. The beta rays are small in mass, namely about 1/1600 that of a hydrogen atom, but have high velocity, and moderately high penetrating power. Beta rays will pass through an ordinary thin piece of glass tubing and have a velocity of from one hundred thousand miles per second up to that of light. The alpha rays are positively charged, and the beta rays negatively charged. The gamma rays are vibrations in the ether similar in character to X-rays, but of much shorter wave-length, and have a higher penetrating power than X-rays.

After it was shown that the mass of the alpha particle was comparable to that of the helium atom, Rutherford stated that the alpha particle undoubtedly was a helium atom carrying two positive charges. It remained for Ramsay and Soddy[53] to prove this statement by actual experimentation. They dissolved a radium salt in a little water in a tube which had been previously evacuated, and collected the gases which were evolved. These were purified and were shown to contain helium. On allowing the radium solution to stand, and pumping off the gases once more, a second amount of helium was obtained after proper purification. In other words, helium was being formed constantly from the radioactive changes going on in the solution.

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[52] Onnes: *Comm. Phys. Lab.*, Leyden, No. 119.

When a radioactive change takes place, therefore, with the elimination of the alpha particle, it means that since helium has an atomic weight 4, the atom which is produced by the change has an atomic weight which is equal to that of the first element minus 4. For example, in Table I, the radium emanation atom explodes with the elimination of an alpha particle, and gives a new atom Radium A with an atomic weight 218 which is less by 4 than the atomic weight of radium emanation mentioned, namely 222. It can be readily seen in the table that wherever an alpha particle is eliminated in the radioactive change this condition maintains. The table is not complete for the sake of simplicity, but it is sufficient to illustrate the point under discussion.

TABLE I.

The Uranium-lead Radioactive Series.

	Atomic weight.	Rays.	Half-life period.
Uranium 1	238	Alpha	5×10^9 years.
Uranium X_1	234	Beta	23.5 days.
Uranium X_2	234	Beta and gamma	1.11 min.
Uranium 2	234	Alpha	2×10^6 years.
Ionium	230	Alpha	10^5 years.
Radium	226	Alpha and slow beta	1,690 years.
Radium emanation	222	Alpha	3.85 days.
Radium A	218	Alpha	3.05 minutes.
Radium B	214	Beta and gamma	26.8 minutes.
Radium C	214	Alpha, beta and gamma	19.5 minutes.
Radium D	210	Beta and gamma	16.5 years.
Radium E	210	Beta and gamma	4.85 days.
Radium F (polonium)	210	Alpha	136 days.
Radium G (lead)	206		

As already shown in the earlier part of this paper, radium is widely disseminated through the earth's crust in rocks and minerals. Although the amounts are locally extremely small, the total in the earth's crust is relatively large. It has been generally believed that helium in the atmosphere has been derived from radioactive changes in the earth's crust, and radioactive changes have also been generally accepted as the origin of the helium in gases from mineral springs, etc. Such an explanation does not account for the neon and other rare gases in the atmosphere nor for the neon which has been found in the gases of certain springs. The classic work of Ramsay and Cameron [54] has shown that if a solution of copper nitrate were treated with radium emanation not only was lithium found in the solution, but the gas which was afterwards pumped from the bulb, consisting mostly of hydrogen and oxygen from the decomposition of the water, after proper purification gave the argon spectrum, but showed no helium lines. The gas, however, contained .34 cubic centimetres of nitrogen. When distilled water was treated with the emanation, neon with a trace of helium was obtained, but no argon. There was present, however, .307 cubic centimetres of nitrogen. This work has not been generally accepted owing to the fact that the neon can be detected in extremely small quantities of air, and it has been assumed that there was probably some leak in the apparatus used.

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[53] *Proc. Roy. Soc.*, V, 72, p. 204, 1903.

Other work has at least indicated the possibility of results of this character. Collie and Patterson,[55] working separately, obtained identical results, which seem to indicate the possible formation of neon with traces of helium by the passage of an electrical discharge at low pressure in hydrogen.

Mason [56] obtained results of a similar character. Others, particularly Strutt, were not able to duplicate the results and the whole matter has been left in a rather unsatisfactory condition.

Radioactive changes take place at a very definite rate. The half-life period (see Table I) represents the time required for half of any particular radioactive element to change into the next disintegration product. For example, the half-life period for radium emanation is 3.8 days, which means that starting with any definite quantity of the emanation, after 3.8 days we would have half of the original gas left. At the end of a second similar period, half of what was left would be changed, and we would, therefore, have actually one-quarter of the original amount. In other words, the element changes according to an exponential law. This being so, it is not difficult to calculate the volume of helium that can be obtained from any given weight of a radioactive element, and we find that the volumes so obtained are extremely small. Two thousand pounds of uranium metal, together with all its disintegration products in equilibrium will only produce 110 cubic millimetres of helium per year. It can, therefore, be readily seen that in order to give the total volume of helium which is in the atmosphere a very considerable time, even from the geological standpoint, must have elapsed for the necessary radioactive changes to have taken place. It also shows that in order to account for the helium evolved in gases from certain mineral springs there must have been a very large portion of radioactive material available within the area through which waters of the springs percolate.

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[54] *Jour. Chem. Soc.*, **91**, 1593. *Ibid.*, **93**, 996. *Ibid.*, **93**, 992.

[55] *Trans. Chem. Soc.*, 1913, **103**, 419. *Proc. Chem. Soc.*, 1913, **29**, 217. *Proc. Roy. Soc.*, 1914, A, **91**, 30.

[56] *Proc. Chem. Soc.*, 1913, **29**, 233.

COMMERCIAL PRODUCTION OF HELIUM.

Use of Dirigibles During the War.—Before the war the Germans had spent many years in the development of a type of dirigible which received the name of zeppelin, after Count Zeppelin, its inventor. These ships were constructed of a number of separate compartments, and had a rigid frame work built either of aluminum or later of an alloy of aluminum, called duralumin, which has a tensile strength of mild steel and a specific gravity only a little heavier than that of aluminum. With a capacity of from one to two and a half million cubic feet of hydrogen, these vessels were able to travel at from 50 to 75 miles per hour, and to make long journeys without serious trouble. A trip of one thousand miles was a small undertaking, and even two thousand miles was not impossible. Since the war the feat of the R34, a British dirigible, in crossing the Atlantic is typical of what may be expected from these monsters of the air.

In the early stages of the war, the Germans used their dirigibles largely for bombing purposes, particularly over London and the munitions districts of England. Although the damage done from these bombing excursions was somewhat minimized at the time, there is no question, from post-war information, that the damage was much greater than the public was allowed to believe while the war was in progress.

Another use for the dirigible which did not appeal so strongly to the public, but which was recognized by military and naval men as probably being more important than the one already mentioned, is the special adaptability of the dirigible for scouting purposes. The Germans used their air fleet to good purpose along this line. The German fleet would never venture from port without two or three dirigibles floating overhead, and these were able to inform the fleet below at all times of the near approach of British war vessels. In this manner, the German fleet could or could not, as it saw fit, accept battle or retire to its base. It has been stated that at the battle of Jutland a dirigible circulating above the Grand Fleet kept the Germans fully informed of the position of the British battleship division while they were engaging the British armored cruisers.

Colonel F. Lucas, in charge of British dirigibles during the war, informed the writer that if it had not been for the German dirigibles he had no doubt but the British fleet would have caught and destroyed the German fleet. The British claimed that one dirigible was equivalent for scouting purposes to six fast cruisers.

The French and British had no dirigibles at the start of the war, but later made haste as rapidly as possible to repair the deficiency. They recognized, however, on account of the experience they gained from the defence of London and other important points in England that the dirigible was not only vulnerable, but extremely so against a well-organized attack. The Germans recognized this also, and, therefore, invariably made their attacks on England at night, and operated from a high altitude in order to minimize attacks by airplane, for a single incendiary bullet fired into a dirigible would probably bring the huge ship down within a few moments a mass of flames. The inflammability of the hydrogen was the one weak spot in this method of attack, and the British realized this quite early in the war. In addition, the constant danger of such a death had a strong effect on the nerves of the operating crews, so that, perhaps, the dirigibles were not as efficient as they otherwise might have been.

The answer, of course, was a non-inflammable gas sufficiently light to take the place of hydrogen as a lifting force. There is only one gas known which has these qualities, namely, helium.

The use of helium would have still further advantages. It diffuses through a fabric at about 75 per cent. of the rate of hydrogen. Owing to the non-inflammability of the gas, it would be possible to put the engines up in the framework of the dirigible, and in this way get a direct drive giving very much increased speed for any given horse-power. On the other hand, it would be necessary to make some improvements in the design of the dirigible in order to prevent waste of gas by valving. The Army and Navy Air Services are working on these problems at the present time.

Initiation of the Helium Project.—As already stated, helium is found in the atmosphere to the extent of one part in 185,000 by volume. It is found in gases from springs, etc., but during the early stages of the war neither the French nor British seemed to have any knowledge of a source of helium that would be sufficient for the purpose outlined.

On February 28, 1915, Sir William Ramsay wrote a personal letter to the writer in which, among other things, he said, "I have investigated blowers, that is, coal-damp rushes of gas, for helium for our government to be used in dirigibles. There does not appear to be anything in the English blowers, but I am getting samples from Canada and the States." He then proceeded to state that personally he did not feel that the idea was at all practical, and also expressed his opinion that, owing to the fact that airplanes could operate successfully against dirigibles, their use was not as important as the Admiralty seemed to believe. At the time this letter was received, the writer was fully aware of the work of Cady and McFarland on natural gases of Kansas, already described, although Ramsay and the British scientific men apparently had forgotten this work. It was, therefore, a question of whether Ramsay and the British government should or should not be informed concerning this work of Cady and McFarland. At the time, all government officials were being strongly urged by frequent communications to remain neutral in every sense of the word, and after several weeks of deliberation, the writer decided not to inform Sir William of the large source of helium which was available in Kansas in the natural gas wells of that State. Whether he was or was not right in this matter is a question for individual judgment.

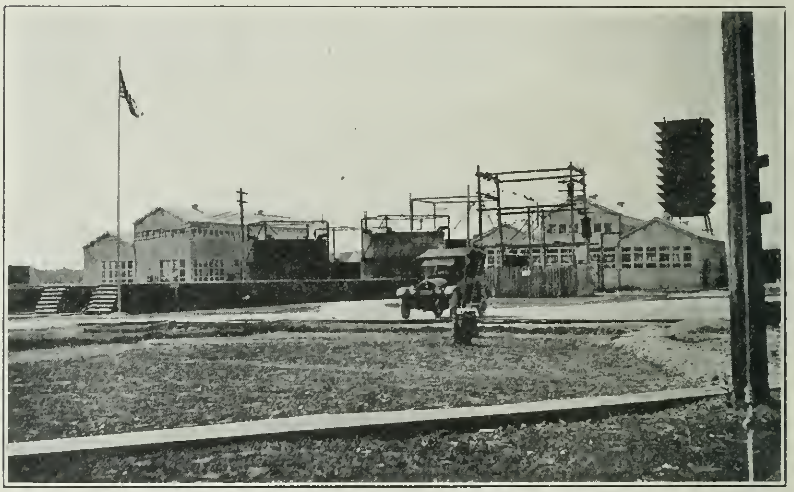
In April, 1917, the writer attended a meeting of the American

Chemical Society in Kansas City, Missouri, where a paper on the presence of rare gases in certain natural gases of Kansas was read by Mr. C. W. Seibel, of the University of Kansas, who had worked under Doctor Cady. Following this paper, in the open discussion, the writer mentioned the possible use of helium in dirigibles and advocated that the matter be taken up seriously. Mr. G. A. Burrell, of the Bureau of Mines, had, a short time before this, learned of the interest of the British in helium, and had also recognized the possibilities of the natural gases of Kansas as a source of supply. In the following June, the whole question was brought to the attention of Dr. F. G. Cottrell and Dr. Van. H. Manning, Director of the Bureau of Mines, and approval was given by the Director to Messrs. Burrell and Moore to take the matter up with the Army and Navy. Major (now Colonel) Chas. DeF. Chandler, in charge of the Balloon Division of the Air Service, was interviewed, and he immediately showed great interest in the project. Colonel Chandler deserves great credit for his broadmindedness and foresight in connection with this whole work. The matter was also brought to the attention of the Navy officials, and they became also intensely interested. Commanders A. K. Atkins and H. T. Dyer and Mr. G. O. Carter represented the Navy, and it is due to the interest of these men and Colonel Chandler that the necessary funds were ultimately made available, and the helium project was actually made possible. The importance of the production of helium as a war measure received considerable impetus about this time from a visit to this country of Commander C. D. C. Bridge and Lt. Commander L. C. Locock, of the British Navy, for which visit Major R. B. Owens, Secretary of the Franklin Institute, was largely responsible.

In order to separate helium from natural gas, it was necessary to use a refrigeration process which would liquefy everything present except the helium. To do this, since the helium-bearing natural gases were high in nitrogen, it was necessary to ultimately reach the temperature of liquid nitrogen, namely −195.7° C. The separation of oxygen from nitrogen by refrigeration methods had taken a very considerable period of experimentation and involved a large outlay of capital. This meant separating 21 per cent. of one gas from 79 per cent. of the other. If in the preparation of oxygen a purity of 98½ per cent. is obtained, the result is considered satisfactory. In obtaining helium from natural gas, however, it would be necessary to start where the other work left off, owing to the fact that the gas to be treated would contain not more than one per cent. helium. The undertaking, therefore, was an extremely difficult one.

For this reason, it was decided to use three processes, hoping that one at least would solve the problem quickly and efficiently. At the time there were two commercial companies in this country making oxygen from liquid air, namely, the Air Reduction Company of New York, using the Claude process, and the Linde Air Products Company of New York, using the Linde process. In addition, the Bureau of Mines through Dr. Cottrell had been in touch with Mr. F. E. Norton, who had a process which could be applied to this work called the Jefferies-Norton process.

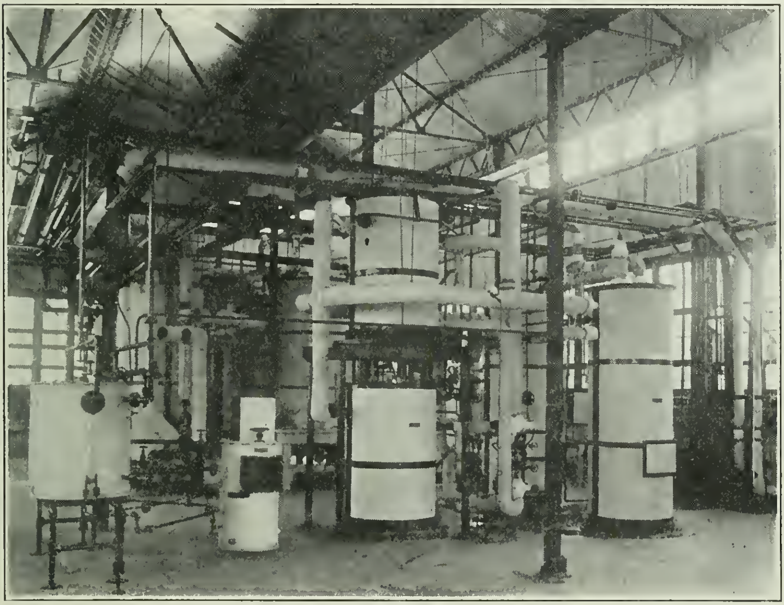
FIG. 1.



Exterior of Plant 1 (Linde System), Fort Worth. The building on the right is the compressor building, and on the left the "process" or refrigeration building.

Funds were allotted to the Bureau of Mines for the erection of three experimental plants, representing the three processes described above. Two of these plants (the Air Reduction and the Linde) were placed at Fort Worth, and the third (Jefferies-Norton) was located at Petrolia, Texas. The reason for this location was that the Bureau of Mines, making a quick survey, had found that the natural gas in the Petrolia, Texas, field contained .93 per cent. helium. In addition, the volume of the gas was reasonably large, since it was possible at the time in question to pump as much as fifteen million cubic feet of gas per day from the wells. This gas was piped to Fort Worth, Dallas, and other towns, and an arrangement was made with the Lone Star Gas Company, of Fort Worth and Dallas, to use this gas from the main pipe line, and allow the return of the processed gas after the helium had been extracted to the pipe lines of the company going to Fort Worth and Dallas. This meant that the government would only have to pay for the actual loss of gas during the processing.

FIG. 2.



Interior of Process Building, Plant 1, Fort Worth. Forecoolers and interchangers are shown in this picture. The column or still is hidden by the rest of the equipment.

Meanwhile, some small developments along similar lines had been going on in Canada. Professor J. C. McLennan, of Toronto University, had been asked by the British Admiralty to also look for sources of helium, and he had located two sources of natural gas in Canada carrying helium, namely, in Ontario and Alberta. The helium content was respectively .34 and .33 per cent., and it has been estimated that the two sources together would give a possible supply of ten million cubic feet of helium per annum. In 1917, a small experimental station was set up at Hamilton, Ontario. Very little progress was made for a considerable time, and in 1918 it was only possible to raise the percentage of helium in the gas to 5 per cent. In the fall of 1918, another station was established at Calgary, Alberta, and more rapid progress was made from that time. The first product contained about 5 to 6 per cent. helium, and this was re-processed until the purity was from 85 to 90 per cent. The total volume of helium produced in a run rose from about 300 cubic feet to more than 700 cubic feet. The plant, however, was small, and the operations rather intermittent, and after the war the plant was shut down. Efforts to obtain sufficient capital to make enlargements and improvements since the war have not been successful.[57] Associated with Professor McLennan were Professor John Satterly and Mr. J. Patterson, who were responsible for a good deal of the success attained.

Whereas the Canadians actually began on their experimental work a little before we did in this country, there was no comparison between the rapidity of progress achieved. Plants No. 1 (Linde process) and No. 2 (Air Reduction) were able to get started considerably before Plant 3 (Jefferies-Norton), as the equipment they used was largely their standard equipment for making oxygen and nitrogen. Necessary modifications, however, were introduced later on. Plant No. 1 commenced to operate March 6, 1918, and made its first helium on April 8, 1918, when some gas analyzing 27 per cent. helium was obtained. This purity was increased after a few months, until in the early part of July a grade of over 70 per cent. was obtained, and in September the plant was operating very consistently, producing an average of from 4000 to 6000 cubic feet of 70 per cent. helium during each operating day. It was necessary to re-process the gas in order to raise its purity to what was desired, namely, over 90 per cent. The impurity of the 70 per cent. material consisted almost entirely of nitrogen, but if the grade of the gas dropped below 60 per cent. helium, there was a small amount of methane in the mixture as well as hydrogen. The methane, as well as the nitrogen, was easily removed by re-processing.

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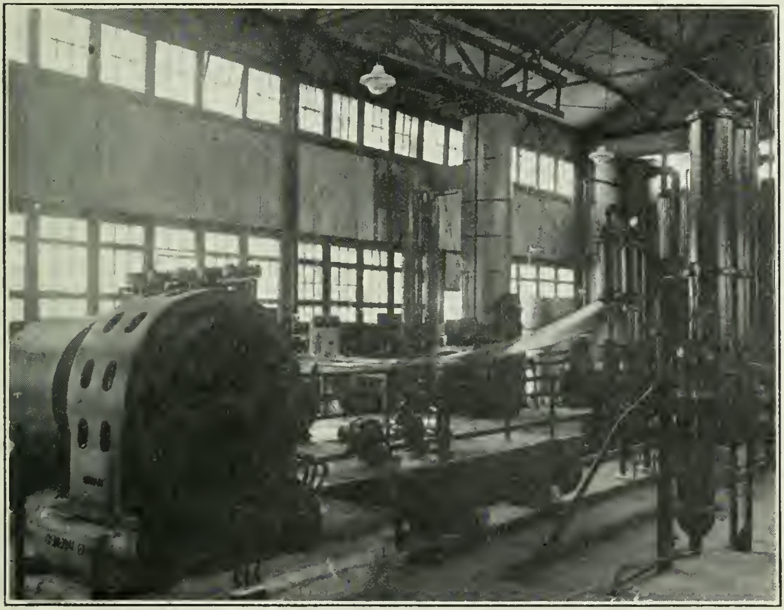
[57] McLennan: Helium, Its Production and Uses, *Jour. Chem. Soc.*, 693. p. 923, 1920.

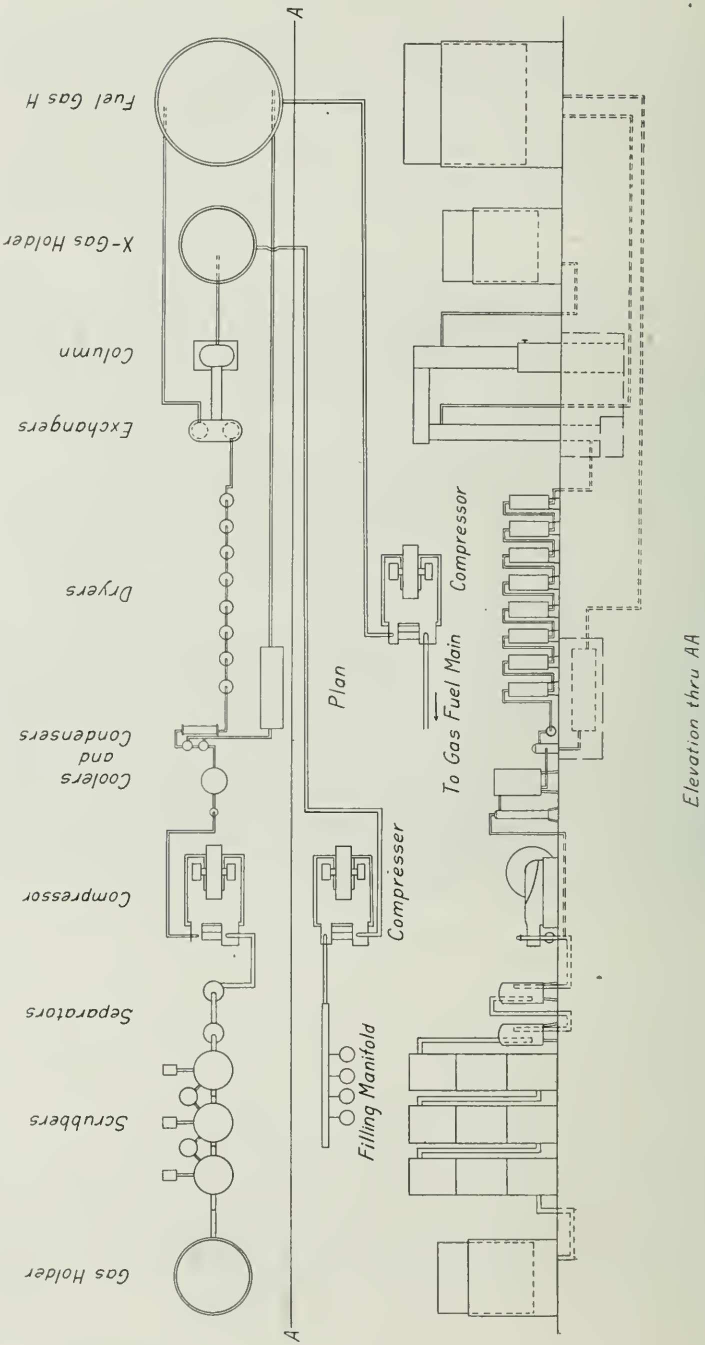
Plant No. 2 began to operate May 1, 1918, and very quickly obtained some helium, as, on May 13, they produced some gas of a grade between 60 and 70 per cent. helium. The operations of Plant 2, however, were as a whole not as successful as those of Plant 1. This was partly due to the fact that more energy and interest on the part of the parent company was put into Plant 1. Apparently the Linde Company had a conception of the importance of the project and made every endeavor to make it a success. The engineering force in connection with Plant 2, however, was thoroughly efficient and alive to the value of the work, especially the chief engineer of the Air Reduction Company, Mr. M. H. Roberts. In addition, the policy adopted by the Linde Company of looking ahead, and having on the ground the necessary material for a change in plant operation provided what was being tried out was not a success, did more toward obtaining their ultimate success than did the actual superiority of their process over the Claude process used by the Air Reduction Company.

FIG. 3.



Inside view of Plant 2 (Air Reduction Company), Fort Worth. The still and interchangers are shown in the centre background; the tops of the calcium chloride driers just behind the motor and the carbon dioxide removers to the far right.

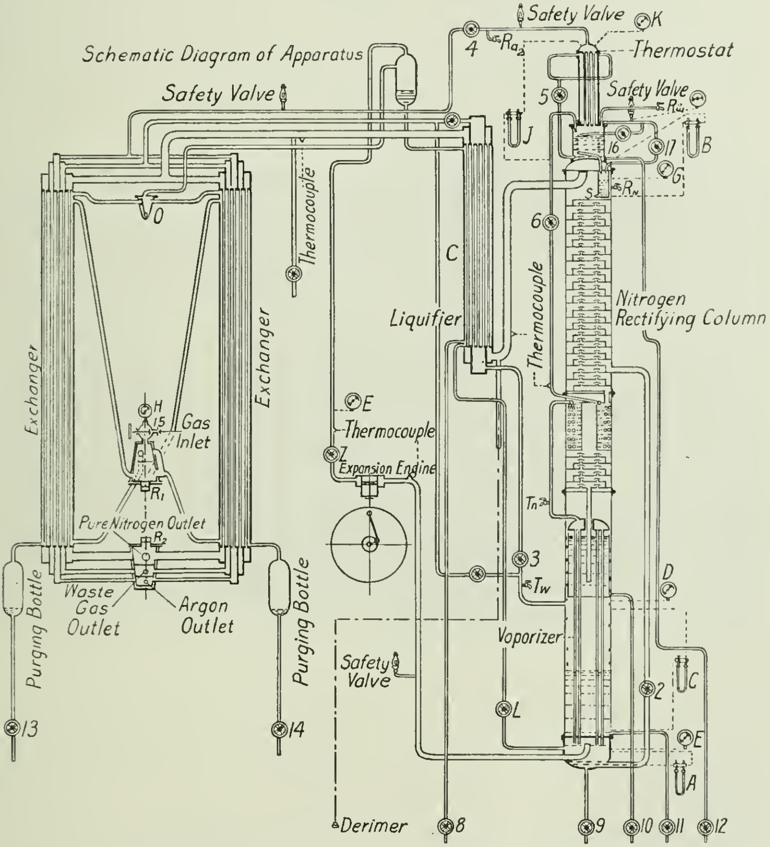
FIG. 4.



Schematic drawing of Plant 2, Fort Worth, Texas.

At the time of the armistice 147,000 cubic feet of helium, averaging 93 per cent., was on the dock ready to be loaded for Europe. This gas had been obtained during the experimental work. Altogether about 200,000 cubic feet of helium was produced by Plants 1 and 2.

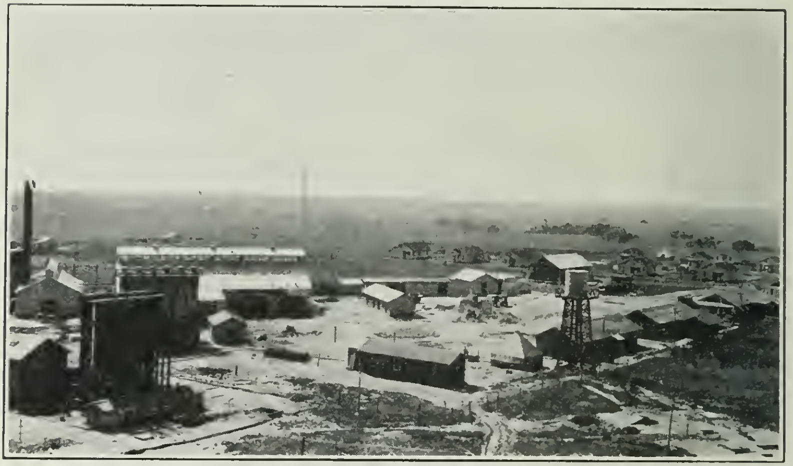
FIG. 5.



Schematic of Still and Interchanger, Plant 2, Fort Worth. During the war for purposes of secrecy helium was called "argon"; hence "argon outlet" on the schematic instead of "helium outlet."

Owing to the better results obtained by Plant 1, it was decided by the Army and Navy that a large production plant should be built based upon the equipment and operation of Plant 1. With this in mind, it was thought advisable to stop the experimental work in connection with Plants 1 and 2, and, therefore, on January 23, 1919, the two plants were shut down. A large production plant has since that time been slowly but steadily going up, and on January 1, 1921, was nearly ready to start regular operations. This plant involves an expenditure of about two million dollars for both buildings and equipment. It was constructed under direction of the Bureau of Yards and Docks and will be operated under supervision of the Bureau of Steam Engineering of the Navy. It consists of six units, five of which are operative, and one is to be retained as a spare. Each unit is designed to handle approximately 44,000 cubic feet of natural gas per hour, which gives an approximate total per day of five million cubic feet. Just what recovery the plant can obtain, of course, is not yet known, but if it obtains an average recovery of 60 per cent. on the helium, it will have, on the five million basis, a capacity of approximately thirty thousand cubic feet of 90 per cent. helium per day. It is hoped, however, that the grade of the final product can be raised to not only 93 per cent., but even 94 per cent., or a little better.

FIG. 6.

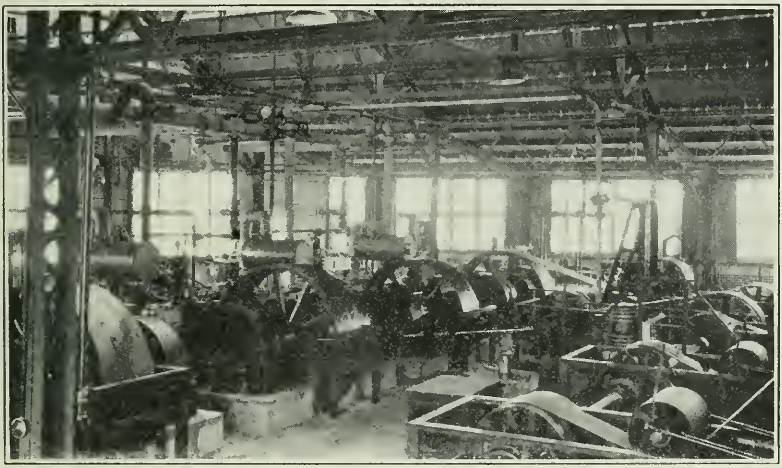


General view of Plant 3 (Jefferies-Norton System). The plant is shown to the left; the gasolene absorption towers of the Lone Star Gas Company in the left foreground; and the living quarters to the right.

Plant 3 at Petrolia had many obstacles to overcome. Its location was poor from the transportation point of view, but it was thought that its location, close to the Lone Star Gas Company compressor plant, would have many advantages. For experimental purposes, it was decided that it would not be necessary for Plant 3 to have its own complete compressor outfit, as it could get the gas from the Lone Star Compressor Station at from 225 to 250 pounds, and could then boost it with one compressor up to the operating pressure of 300 pounds. This arrangement eliminated a considerable amount of equipment at the start, and enabled the plant to get into operation a little earlier.

On the other hand, the apparent gains by this system were more than offset by difficulties which were not anticipated. Owing to the construction and operation of the Lone Star gasolene absorption plant frequent "slugs" of salt water and seal oil (used as an absorbent for the gasolene) were shot over to Plant 3 along with the gas, and on each occasion it was necessary to shut down the operations of the government plant. Notwithstanding these and other difficulties, a run was obtained on April 2, 1919, during which helium of a grade of 19.8 per cent. was produced. On April 17, 21 per cent. helium was made, but the plant has not been able to produce helium regularly and consistently, the above results being obtained on specially favorable runs. The Jefferies-Norton process was given an extremely difficult undertaking right at the start in applying it to the extraction of helium from natural

FIG. 7.

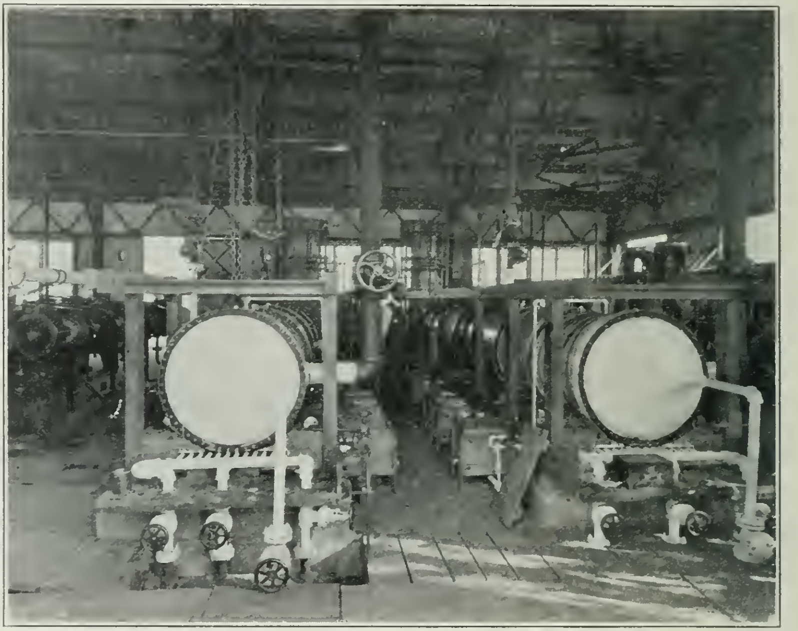


Compressors in Plant 3, Petrolia, Texas.

gas where there was less than one per cent. of the material to be extracted in the product used. In addition there was no intermediate experimental work done between a small laboratory equipment and the installation of Plant 3, which is probably the largest single refrigeration unit in the world. Under these circumstances the performance of the plant was quite remarkable.

Since the time mentioned a number of changes have been made in Plant 3, with the object of improving its operating efficiency. During the fall of 1920 some radical changes were made in the whole design of the plant, and these will probably be ready for testing out in February, 1921.

FIG. 8.

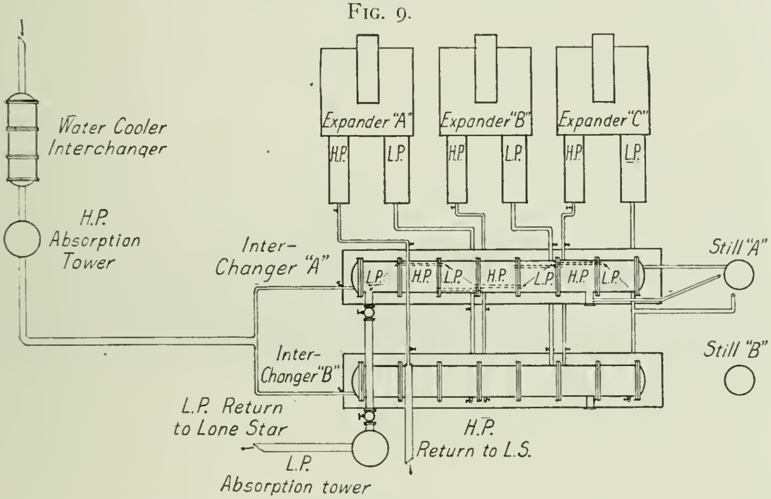


Interior, Plant 3, Petrolia, Texas. This picture shows the two parallel interchangers before being covered with insulating material. The different sections are plainly shown. The two stills are seen in the rear centre, and the expansion engines on the left.

Theory of Refrigeration.—One way by which work can be measured is by the product of pressure and volume pv. It has been shown that for ordinary gases at constant temperature, pv is not quite constant. If air is taken as an example, the value of pv at 0° C. increases as the pressure falls, which gives rise to cooling on expansion. In the case of hydrogen at the same temperature, the product pv decreases with fall of pressure, and, therefore, in the case of this gas slight heating takes place on expansion. There is, however, in the case of hydrogen a reversal at about −200° C., and if the gas is pre-cooled below this temperature before expansion, a cooling effect instead of a heating effect is obtained.

In 1854 Joule and Thomson carried out some extremely interesting experiments, which showed that highly compressed gas (with the exception of hydrogen, and, as more lately ascertained, helium) when expanded through a porous diaphragm becomes decidedly cooler. This is due to the work which is done against molecular attraction. There is, therefore, in gases a cohesive force which increases with the density. If we were dealing with perfect gases, following exactly the laws of Gay-Lussac and Mariotte, the gases should not cool at all during expansion. Gases, however, are not perfect in this sense of the word, and a small cooling effect actually takes place, the effect being stronger the less perfect the gas is. The cooling "d" for air for a fall of pressure of (p_1-p_2) atmospheres is, according to a formula derived by Joule and Thomson: $d=0.276\ (p_1-p_2)\left(\frac{272}{T}\right)^2$ in which T is the absolute temperature of expansion.

FIG. 9.

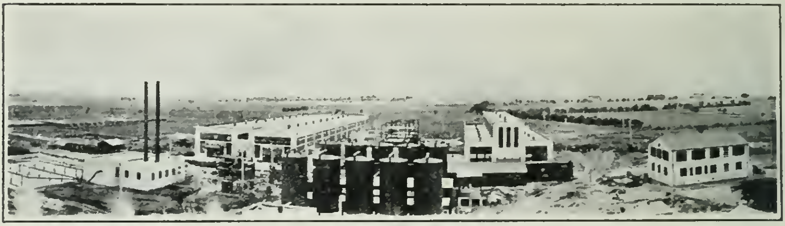


Schematic of Plant 3, Petrolia. There are two parallel interchangers with a still to each interchanger. The three expansion engines can be used either on one still and one interchanger or on both pairs so that the capacity can either be one and a half million cubic feet of raw gas per day or three million cubic feet.

From this formula it can be seen that the fall of temperature "d" depends on the fall of pressure. In addition the lower the temperature, the larger the temperature fall caused by expansion, since T becomes less.

If instead of expanding a compressed gas through an expansion valve, the gas is allowed to do work in an expansion engine which is practically nothing but a reversed compressor working against some external resistance, which may be either a brake or more commonly a small generator, we will find that the gas becomes cold very rapidly and parts of the expansion engine will become coated with frost. This method of cooling by means of adiabatic expansion in an engine with a piston is very efficient and is theoretically covered by the formula $\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{0.29}$.

FIG. 10.



New Helium Production Plant (Linde System), Fort Worth. The cooling pond is seen on the extreme left with a large number of cylinders piled in the rear. Of the two large buildings, the one on the left is the compressor building, and the one on the right the "process" building. The carbon dioxide removal towers are in the centre foreground, and the laboratory and office on the right.

The results obtained are much better than expansion through a nozzle except near the critical temperature of the gas, when the nozzle becomes nearly as efficient as the expansion engine. In order to get the necessary refrigeration with nozzle expansion it is necessary to go to very high pressures, whereas only moderate pressures are required with an expansion engine. The Linde system of refrigeration which was used by Plant 1, therefore, involved much higher pressures than the Claude system of refrigeration used by Plant 2, which used an expansion engine. This was the main difference in fundamental apparatus between the two plants, although the equipment varied considerably in detail.

In both plants the initial pressure to which the gas was compressed could not be maintained, as the gas in each case was expanded from a higher pressure to a lower pressure when it entered the fractionating column or still.

In practice, in order to obtain the necessary temperatures, and in order to conserve power, and, therefore, costs, a heat interchanger is always used in connection with either system. This consists of a series of coiled copper tubes, one tube inside another with a counter flow of gases, the cold gas from the still going in one direction and cooling the warm fresh gas before it is fed either to the expansion valve or to the expansion engine. Sometimes the interchanger consists of a series of straight tubes placed very close together somewhat similar to a tubular boiler. The ideal condition to be aimed for is to have the temperature of the outgoing gas after passing through the interchanger practically the same as the temperature of the fresh gas entering the interchanger.

Since the liquefaction of the gas is dependent upon two factors, namely, its temperature and pressure, it is important to keep as high a pressure in the still as possible in order to be able to work at higher temperatures. On the other hand, if the expansion does not take place down to relatively low pressures a very considerable amount of refrigeration is lost, and the necessary temperatures are not attained. The Jefferies-Norton system, used by Plant 3 at Petrolia, gets around this difficulty by holding the initial pressure all through the interchanger and still. After the gas has passed through the still, it is expanded through a series of three expansion engines, and the exhaust gas from these engines goes into the outer sections of an interchanger of a tubular boiler type, thus cooling the incoming gas, which passes through the tubes themselves (see Fig. 9). By working the expansion engines at different temperatures, and thus liquefying the different hydrocarbons in the natural gas progressively instead of cooling everything down to the same temperature, additional efficiency is possible.

Plant No. 1. Helium Production Plant.—In so far as its essential features are concerned, the new helium production plant at Fort Worth is a duplicate on a larger scale of the original experimental plant, using the Linde system. The outline which follows is, therefore, a description of the new plant rather than the old one, although the process is practically identical.

The natural gas is first treated for the removal of carbon dioxide, which is present in quantities varying from .2 to .3 per cent. This is done by bringing the gas under low pressure in contact with lime water in specially designed scrubbers in which the gas is sprayed with lime water for a sufficient length of time to reduce the carbon dioxide to the necessary maximum. The CO_2 removal system consists of five units, one of which is a spare. In each unit the incoming gas passes from the top of the scrubber to the bottom and comes in contact with a solution of slacked lime, which is sprayed into the tank by a series of nozzles near the top. The gas is then passed to the top of a similar scrubber in which it comes in contact with a fresh lime solution. The lime water flows from the scrubbers, is filtered and re-circulated. The natural gas freed from carbon dioxide passes under 3-inch water pressure to two 5000 cubic foot holders which act as reservoirs for the compressors. The heat of compression is removed in the usual way through intercoolers between each stage of compression and through aftercoolers in which the gas is cooled by circulating water.

In addition to the usual Linde method of obtaining low temperatures by means of nozzle expansion, a carbon dioxide cycle is also used as a gas forecooler. The compressed gas is led through this forecooler, in which most of the water vapor is removed by freezing. The cooled gas goes from the forecooler to the gas interchangers, where it meets the cold gas returning from the still. This returning gas precools the incoming gas to a temperature sufficiently low to give the desired effect after expansion. Arrangements are made in connection with these interchangers so that there is a progressive cooling first carried out by the returning vapors of the heavier hydrocarbons, and ending up with the return nitrogen, which is liquefied in the upper portion of the still. From the interchangers the gas is expanded through a nozzle into the still and enters the bottom of the still partly in the liquid and partly in the gaseous state. The still consists of three units, each unit being a rectification column, with a condenser at the top and a receiver at the lower end. The gas enters the lower unit and passes up through the middle unit, and thence to the top one. Each unit is so designed as to remove a definite portion of the constituents of the gas in the liquid state, and deliver a definite portion of the gas in a gaseous state to the next higher unit. A definite temperature gradient is maintained in each unit and the constituents are progressively removed by liquefaction and re-evaporation and go back through the interchangers. In order to get a reasonably high grade product, such as 70 per cent. helium, it is necessary to liquefy the nitrogen in the gas as completely as possible. To do this, and not have the vapor pressure of the nitrogen too high, the upper unit of the still must be at the temperature of liquid nitrogen. In order to accomplish this a separate nitrogen cycle is used, in which pure nitrogen is liquefied and surrounds the condenser of the upper unit of the still. The make-up for this nitrogen cycle in the original experimental plant had to be purchased, but the new plant is designed to obtain the necessary make-up in the form of pure nitrogen from the operations of the plant itself, in which a sufficient amount of the nitrogen in the natural gas will be completely separated from the methane and other hydrocarbons.

The liquids collected in the receivers of each unit are used as required in the condensers of the middle and lower units. All outgoing gases from the still pass through the gas interchangers and gas forecoolers, thus precooling the incoming natural gas. These outgoing gases are mixed at the final outlet, and are returned to the mains which supply the cities of Dallas and Fort Worth. The gas, therefore, is simply robbed of its helium and a small portion of nitrogen, the rest of the gas being used for commercial heating and lighting purposes.[58]

Plant No. 2.—Fig. 4 represents a schematic of Plant No. 2 of the Air Reduction Company, using the Claude system. The natural gas is taken from the holder at atmospheric pressure, and led through a series of scrubbers, filled with hollow tile, over which caustic soda solution is circulated. The gas freed from carbon dioxide then goes through separators, in which a good deal of the moisture is eliminated, and from the separators to the compressor, in which the gas is compressed to 600 pounds. It then goes through a series of coolers, in which it is cooled to atmospheric temperature by water, and then through oil removers. It is then passed through a series of eight dryers, filled with porous calcium chloride. In the Claude system it is necessary to have a reasonably dry gas, owing to the fact that the tubes in the interchanger are extremely small. After passing through the dryers the gas goes to the interchangers, where the incoming gas meets the cold gases coming back from the still in a similar manner to the Linde plant. Plant No. 2, however, made no use of a carbon dioxide cycle, and had no auxiliary refrigeration system. After going through the interchangers 25 per cent. of the gas is run through a liquefier, which is cooled by the returning gases from the still before these go to the interchangers. The other 75 per cent. of the gas is expanded through a small vertical expansion engine from the original 600 pounds pressure down to 120 pounds. This portion of the gas from the expansion engine, therefore, enters the bottom of the still containing some spray. Fig. 5 gives an outline of the arrangement of the still and interchangers. The liquid from the liquefier "C" drains into the bottom of the still and is led up to the rectifying column, from which it drops into the various compartments below, filling each compartment and overflowing to the one beneath. The gas coming from the expansion engine is partially liquefied in passing up through the tubes of the condensers, and finally reaches the top condenser, which is cooled by the expansion of a liquid consisting of a mixture of liquid nitrogen and methane. The last traces of the methane in the gas are practically all removed at this point, and also a considerable proportion of the nitrogen. The helium with the unliquefied nitrogen passes into the helium reservoir.

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[58] Owing to the contract between the government and the Linde Air Products Company, it is not possible to write a more detailed description of the equipment than is given.

This plant was able to make helium, and to make it at times fairly consistently, but it could not deliver helium steadily, as the necessary temperatures could not be maintained at the top of the still, if the helium was allowed to flow out at a constant rate. Whereas the plant on the mechanical side could operate steadily, the helium could only be delivered periodically for the above reason.

Some changes in the column were made toward the end of the experimental period, but these changes did not improve the operating results.

Plant No. 3 (Jefferies-Norton system) was located at Petrolia, close to the compressor station of the Lone Star Gas Company. As already stated, this plant holds its initial pressure on the gas through the interchanger and still, and only expands the gas through an expansion engine after the gas has passed through the still. In this respect, it is different from the Claude system.

In addition there are three expansion engines working at different temperatures instead of one. In this way the hydrocarbons contained in the gas are liquefied progressively, and it is not necessary to reduce all of the gas to the same temperature. This increases efficiency and lowers operating costs. Fig. 9 is a diagrammatic sketch of the interchanger and still. The gas enters the interchanger at a pressure of 300 pounds, and passes through the tubes in the interchanger. There are seven sections in the interchanger, alternatively low pressure and high pressure, through which the inner high pressure tubes run. Each tube is ¾ inch in diameter, and baffles are placed against the tube sheets, causing the gas to travel a number of times backwards and forwards before it ultimately goes into the next section. The incoming gas, therefore, in going through the tubes traverses each section of the interchanger seven times before it goes into the next section, thus giving a high efficiency on heat interchange. The baffles placed between different sections cause the liquids which are formed in each section to fall to the bottom of the space between the tube sheets of adjacent interchanger sections where they can be drained out through proper drains, and can be expanded back into the outer low pressure sections of the interchanger at points where this expansion will give the best refrigerative effect. It was planned that all of the hydrocarbons would be successively liquefied in the first five sections, except the methane, which would come down in the last two sections, and be used for charging the still. The end of the interchanger, therefore, nearest to the still, would have to have a sufficiently low temperature to liquefy methane from a gas mixture at 300 pounds in order that the still could be charged, and the whole system could function properly. This liquid methane is then charged into the bottom of the still in the inner pot and is used for cooling the portions of the still higher up by expansion through needle valves into reflux coils placed at different points in the still. These coils are to reliquefy the gases coming up through the still through evaporation of liquids in the trays, so that there can be a constant fractionation in the column, the liquid in the trays liquefying the gases coming up through them having a higher boiling point, and they, themselves, evaporating, to be condensed higher up the still. The coils in the upper portion of the column are connected with a vacuum pump, so that liquid nitrogen which is produced at this point can be boiled under reduced pressure, and a very high grade product obtained. It is hoped that this will eliminate the necessity for repurification and its attendant costs.

All gases except the helium and that portion of the condensed gas used in the still coils are re-ĕvaporated back into the last high-pressure section of the interchanger. From this section a portion of the gas goes through No. 3 expansion engine, the expanded gas going into No. 7 low-pressure section of the interchanger, and this cold gas together with the expanded gas from the still coils gives the necessary refrigeration to liquefy the methane. In actual practice the exhaust on this engine has dropped as low as −155° C. to −160° C. All of the high-pressure sections are connected together by "jump tubes," so that the pressure in the three high-pressure sections is the same. Therefore, a part of the gas not used by expansion engine No. 3 is used by engine No. 2, which exhausts into low-pressure section No. 5. The residual gas is expanded through engine No. 1, which exhausts into section No. 3. This, therefore, gives a progressive cooling effect down the interchanger from the warm end to the cold, which results in the fractional liquefaction of the hydrocarbons.

One novel feature of the Jefferies-Norton system is the use of the power generated by the expansion engines. These engines are so connected as to assist the compressor in compressing the incoming gas so that they help to decrease the actual power used in compression.

As already stated, this plant has made helium for short periods containing as much as 21 per cent. of the rare element, but cannot be, at the present time, considered a commercial success, as it has not been able to operate steadily with the production of helium. Mechanically, however, it has done everything expected of it. Besides the troubles already referred to, due to its location, it has been extremely difficult to separate ethane from methane in the interchanger by a fractional liquefaction, as, owing to the low average percentage of ethane after passing the gasolene absorbers (2 to 3 per cent.), the partial pressure of this gas is quite low. At the time of writing some rather radical changes are being made in the plant, involving an auxiliary refrigeration system and a new still of the cascade type. Additional equipment has also been put in to protect the plant from variations in the operations of the Lone Star plant.

Repurification.—Plant No. 1 produced helium averaging about 70 per cent. in purity. The gas produced by Plant No. 2 averaged less than this. It was, therefore, necessary to refine this product up to a higher degree of purity in order to make it available for military and naval purposes.

Plant No. 1 is the only plant that did any experimental work on refining. The 70 per cent. helium which was stored in gas holders was compressed to about 1000 pounds, and passed through the helium forecooler and helium interchangers to a still consisting of a single unit similar to the units of which the regular still was built. The forecoolers and interchangers used on this repurification cycle were similar in number and design to the forecoolers and interchangers used on the regular gas cycle previously described. The one unit still consists of a rectifying column, having a condenser at the top and a receiver at the bottom. Liquid nitrogen was supplied to the outside of the condenser from a closed external nitrogen cycle. The impure helium was expanded into the bottom portion of this still, with the result that the nitrogen was condensed and the purified helium, in grade 92 to 93 per cent., was led from the top of the condenser. This helium as well as the waste nitrogen was used in the helium interchangers and forecoolers to precool the incoming impure gas. The purified helium was compressed to 2000 pounds pressure in cylinders, each cylinder holding 200 cubic feet at this pressure.

By this method it is probable that a gas containing not more than 93 per cent., or at the most 94 per cent., helium can be obtained unless the liquid nitrogen supplied to the condenser by means of the closed cycle is boiled under reduced pressure, in which case the temperature might be dropped below –200° C., with the result of a much higher grade product. This has not yet been done.

Another method of purification which gives promise of great usefulness is the one developed by the Bureau of Mines' helium laboratory at Fort Worth. This work was done by Dr. Leo Finkelstein and Mr. C. W. Seibel.

It was found that at the temperature of liquid air, charcoal was able to adsorb the nitrogen very efficiently, and at the same time had a selective action on this nitrogen, since the helium was adsorbed to only a very small extent. The following table gives in a condensed form the main results obtained in connection with a certain charcoal, which is on the commercial market:

Temperature minus Cent.	c.cm. Helium ads. per gram charcoal.	c.cm. Nitrogen ads. per gram charcoal.	Per cent. ratio.
−190	6.5	302	2.15
−159	4.0	246	1.63
−104	0.85	121	0.70
− 86	0.45	92	0.49
− 75	0.30	70.8	0.42
− 48	0.20	48	0.415

The per cent. loss of helium is small and even the helium, which is adsorbed, can be pumped off by a vacuum pump without being contaminated with nitrogen.

The curve showing the grade produced is exceedingly interesting, as the point at which the curve breaks as regards purity is very sharp. The grade holds steadily at 100 per cent. up to the breaking point, at which point the purity drops rapidly. This condition is extremely convenient and satisfactory for repurification purposes.

The Army is constructing a repurification unit on two railroad cars. One will contain the power unit for generating the necessary current, and the other car will contain the compressors and the necessary refrigeration apparatus for repurification of helium from balloons and dirigibles, after the purity has dropped below the minimum of efficiency. These cars can be sent to any point where they may be needed, and should be extremely useful. A charcoal repurification unit is being designed by the Bureau of Mines, and will be installed in this car for the repurification of helium from dirigibles after use.

Plant Methods for Helium Analysis.—It was extremely important during the experimental work to get quick analyses on the helium content of products obtained in the plants. In order to do this the Air Reduction Company used the Edwards' balance,[59] and the Linde Company used a viscosimeter,[60] in which the gas to be tested was allowed to flow through a minute hole in a piece of platinum foil, the apparatus being calibrated against pure nitrogen. In this manner a determination could be obtained in two or three minutes, and was correct within one or two per cent., provided the helium content was not below 20 or 25 per cent. The Bureau of Standards[61] has developed an automatic recording equipment based on the heat conductivity of gases which has been adapted to the helium plants with considerable success. This apparatus has been used at Plant 3, and will also be used in the large production plant, and an automatic record can be kept of the analysis of the helium produced from a still at all times. The accuracy of these methods all depends upon there being present two gases only. If a third gas, such as methane, is present, it naturally throws off the results very considerably. As, however, a gas containing as much as 70 per cent. helium has, as a rule, nitrogen only as an impurity, all these methods are applicable to the testing of helium of this purity.

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[59] *Tech. Paper No. 89, Bur. Standards.*

[60] *Tech. Paper No. 94, Bur. Standards.*

Production Costs.—The cost of production of helium for Army and Navy purposes is vital in connection with an undertaking such as has been under way. The actual cost of extracting helium on a large scale can be estimated fairly accurately within certain limits. The two plants at Fort Worth had fairly satisfactory operating conditions up to October 1, 1918. At that time, owing to the increased demand for gas in Fort Worth and Dallas, it was necessary for the Lone Star Gas Company to take into their main pipe lines gas from other fields besides the Petrolia field. This reduced the average helium content below 0.5 per cent., and also caused a considerable variation in the hydrocarbon and nitrogen content. This put the plants at a serious disadvantage, and made it impossible to estimate costs under normal conditions. However, the month of September was a satisfactory month for Plant 1, since it ran steadily for 80 per cent. of the time. The actual cost during this month to produce helium of 70 per cent. average grade was $146 a thousand cubic feet, figured on the 100 per cent. helium basis. Of this amount $53.40 went toward the purchase of nitrogen for the "make-up" on the external nitrogen cycle. As the new production plant will make its own nitrogen for this "make-up" in the regular course of operations, this item can be entirely omitted, leaving $92.60. The cost of power in this estimate was figured at one cent per K. W. hour.

The recovery of helium during this month was only 45 per cent. of the helium in the gas. There is no doubt that owing to the experience afterwards obtained that this recovery can be considerably increased. In addition, the capacity of the new production plant is a little over five million cubic feet of raw gas per day as against 700,000 cubic feet for the experimental plant. The difference in overhead and other operating expenses of each plant will be considerable, and should cut the cost of production to a very marked degree. The Bureau of Steam Engineering of the Navy Department estimate that the actual operating cost in the new plant will be $56 a thousand cubic feet of 92 per cent. helium. This does not take into account certain overhead charges and amortization of the plant. As an ordinary business proposition, it would, of course, be necessary to take these items into serious consideration. On the other hand, as an insurance against war, and as an insurance against the destruction of our cities by the dirigibles of other nations in case of war, the original investment in the helium experimental work and in the helium plants can well be written off the books by the nation.

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[61] E. R. Weaver and others: *Jour. Ind. and Eng. Chem.*, 12, p. 359, 1920.

If the Jefferies-Norton process proves to be a commercial success, helium can be manufactured more cheaply than the figure above mentioned. Taking into consideration the average operating costs of this plant, and assuming a recovery of 60 per cent. on the helium, it is possible that this plant may be able to produce helium at $20 a thousand cubic feet, figured on 100 per cent. basis. If the recovery is higher, the cost will be correspondingly lower. This figure, also, does not take into consideration amortization charges.

Professor J. C. McLennan[62] estimates that helium can be produced in his plant in Canada, if necessary changes are made, at less than $50 per thousand cubic feet. This does not include the cost of the gas. He does not, however, give any figures of actual costs to substantiate this statement, and the estimates are apparently based on an equipment which at present cannot produce more than one hundred thousand cubic feet of helium per year.

The costs mentioned above are probably high owing to the fact that helium after once used in a dirigible can be used again by reprocessing. The cost of repurification is not, of course, anything like the cost of original production.

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[62] *Jour. Chem. Soc.*, July, 1920, p. 923.

HELIUM IN NATURAL GAS.

When it was determined, at the beginning of the war, to extract helium for balloons and dirigibles, Mr. G. A. Burrell, of the U. S. Bureau of Mines, had a number of samples of natural gas analyzed for helium, and was fortunate to quickly locate the Petrolia field as one of the best, if not the best, source of helium in the country. This field is located in the northern part of Clay County, Texas, sixteen miles northeast of Wichita Falls and seven miles south of Red River. The field is elliptical in shape, extending about four miles from northwest to southeast, and about three and a half miles from northeast to southwest. At the northwestern end of the field is the town of Petrolia, which is served by the Wichita Valley Railroad.

In 1909 the Lone Star Gas Company laid a 16-inch pipe-line from the field to Fort Worth and Dallas, and for about five years these cities, as well as Wichita Falls, and other smaller towns in the vicinity, were supplied entirely with Petrolia gas. In 1915–16 another line was laid from the Fox and Loco fields in southern Oklahoma direct to Dallas, and the compressor station at Petrolia was also connected north with the Keyes gas field in Cotton County, Oklahoma. The gases from both Keyes and Fox fields are very low in helium, and, therefore, it has been necessary to segregate the gas from the Petrolia field for the use of the government plants. This was accomplished in the fall of 1918 through payment by the government to the Lone Star Gas Company of one and a half million dollars, to limit the production of gas from the Petrolia field to a certain maximum per day. This was done with the idea of partly conserving the gas until such time as the government plants would be ready to operate. Notwithstanding this, at the present time, there is only a few years' supply of gas left in the Petrolia field. A separate pipe line has been lain from Petrolia to Fort Worth to serve the new production plant. A typical analysis of the Petrolia gas is as follows:

	Per cent.
Helium	.93
Carbon dioxide	.25
Oxygen	.54
Methane	56.85
Ethane and heavier hydrocarbons	10.30
Nitrogen	31.13
	100.

There is a variation in the composition of the gas from the different wells in the field, but all within the Petrolia field proper are high in helium. The above analysis is quite representative of the average gas before being treated for the removal of gasoline.

The limited life of the field was recognized two years ago, and, therefore, a survey of the whole country for sources of helium in natural gas was started by the U. S. Bureau of Mines. Director Manning asked the U. S. Geological Survey to assign a geologist to assist the Petroleum Division of the Bureau of Mines in this work. Mr. G. Sherburne Rogers was chosen by Director Smith, of the Survey, and worked most efficiently with the Petroleum Division of the Bureau. After two or three months' work, owing to other demands on the Bureau of Mines' men, Mr. Rogers did the main field work for the rest of the year, and the results he obtained as well as those of the Bureau of Mines' men are contained in a recent bulletin of the Geological Survey.[63] It is to be greatly regretted that this young geologist lost his life the next year while doing professional work in South America.

All analytical work in connection with this report was done by Bureau of Mines' men at the laboratory at Fort Worth, under the immediate direction of Mr. C. W. Seibel. The data obtained in this preliminary survey were not always complete, owing to the necessity for getting as much information in as short a time as possible. In July, 1919, the survey was continued by the Bureau of Mines, the writer being in general charge, the field force being directly under Mr. A. N. Dangerfield, and the laboratory at Fort Worth continuing under Mr. Seibel. About one thousand samples of natural gas have been analyzed for helium, and the larger proportion of these have also been analyzed for their other constituents. All data necessary for a complete appreciation of the commercial advantages of the different wells and fields have been collected, and will be published in due course of time.

During the period of this survey every natural gas field in the United States has been investigated, and the Bureau now has complete information regarding sources of helium in this country. One of the surprising things which has shown up in connection with this survey is the large proportion of natural gases which carry helium in measurable amounts. Undoubtedly, over one million cubic feet of helium is being wasted in this country every twenty-four hours. The number of wells containing 0.2 per cent. or more is large. The number, however, which contain 0.5 per cent. or more is quite limited. In general, the richest gas is found in southeastern Kansas, in the Dexter, Sedan, and Augusta fields. These are the ones originally examined by Cady and McFarland, and some of the natural gases in these fields contain as much as 1½ per cent. helium, but the volume of gas is relatively small as the fields are old. However, it might be possible by a proper collecting system to obtain five or six million cubic feet a day or even more in these localities.

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[63] G. Sherburne Rogers: Helium Bearing Natural Gas, *Professional Paper No. 121, U. S. Geol. Sur.*, 1920.

The state containing the largest number of helium gas wells is Oklahoma. The richest belt runs from southwest to northeast through the Osage country, and connects up with the wells in southeastern Kansas on the north, and with a considerable break connects with the Petrolia field on the southwest. Another break occurs between the Petrolia field and the east Texas field, where a considerable amount of gas carries as much as 0.2 per cent. or even 0.3 per cent. helium. The country in between the Petrolia and the east Texas field has not been drilled. The helium-bearing line strikes northeast through Kentucky and Ohio, where, in Vinton County, Ohio, a very considerable amount of gas, averaging between 0.4 per cent. and 0.5 per cent. helium, is available. In Pennsylvania, New York, West Virginia, Indiana, Kentucky, and Illinois, there is a considerable volume of gas containing from 0.1 per cent. to 0.3 per cent. helium. The western gases as a rule are barren, especially the large supplies of gas in Wyoming and California.

There is a curious relation between the proportions of helium and nitrogen present in natural gas. It is invariably true that helium is never found in natural gas that is not reasonably high in nitrogen. The converse, however, is not true, namely, that all high nitrogen gases contain helium. No definite relation can be established between these proportions, but helium is always accompanied by nitrogen.

The following table gives the analyses of a number of typical gases from different states which carry helium:

Table of Analyses of Natural Gases.

Laboratory No.	State.	County.	Field.	Depth.	Horizon.	Chemical Analyses.					
						Helium per cent.	CO_2	O_2	CH_4	C_2H_6	Residue N_2
274	Arkansas	Sebastian	Williams and Kiblev	....	Pipe Line Sample	.26	.00	.36	97.98	.00	1.40
A55	California	Fresno	Coalinga	....	....	trace	..	..	....	....	....
362	Colorado	Rio Blanco	White River	530	Eocene, Wasatch Stage	trace	.15	.16	97.36	1.75	.58
525	Indiana	Randolph	Southwest	1093	Trenton	.23	.16	.48	73.49	16.86	8.78
142	Kansas	Butler	Augusta	1450–1500	Pennsylvanian	.50	.19	.57	74.74	12.92	11.08
168	Kansas	Chautauqua	Rogers	725	Pennsylvanian	1.28	.00	.83	54.20	.00	43.69
218	Kansas	Franklin	Peoria	719	Pennsylvanian	.17	.49	.71	98.55	.00	.08
198	Kansas	Montgomery	Big Bell	875	Stray sand above Oswego lime	.41	.08	.69	72.23	5.10	21.49
283	Kentucky	Floyd	Beaver Creek	1646	....	.13	.16	.66	77.55	21.13	.37
179	Louisiana	Ouachita	Monroe	2163	Cretaceous, equivalent to Nacatoch	.18	.06	.67	98.02	.00	1.07
303	New York	Genesee	Pavilion	1900	Cretaceous Medina sand	.31	.00	.49	87.96	8.68	2.56
230	Oklahoma	Nowata	Ludowici-Celadon	687	Pennsylvanian	.04	.09	.66	96.54	.00	2.67
348	Oklahoma	Okmulgee	Henryetta	2210	Pennsylvanian	.14	.04	.57	78.19	18.43	2.63
135	Oklahoma	Osage	Pearson	777	Pennsylvanian	.63	.00	.45	59.33	.00	39.59
340	Pennsylvania	Green	Waynesburg	2807–2842	Bayard sand	.10	.00	.87	82.81	14.49	1.73
262	Tennessee	Scott	Glen Mary	1235	....	.36	.18	.65	63.86	31.73	3.22
90	Texas	Clay	Petrolia	1713	Pennsylvanian "Cisco"	.90	.25	.54	56.85	10.33	31.13
88	Texas	Eastland	Eastland	1780	....	.08	.00	.00	87.42	9.19	3.31
143	Texas	Stephens	Breckenridge	3099	....	.21	.00	.12	76.48	19.68	13.50
510	West Virginia	Kanawha	Clendenin	1904	Squaw sand	.10	.32	.32	93.20	4.31	1.75
370	Wyoming	Niobrara	Lance Creek	....	....	trace	.20	.63	69.06	29.19	.92

METHOD OF ANALYZING NATURAL GAS FOR HELIUM.

The method of Cady and McFarland[64] in their earlier work is still used with some modifications and gives excellent results. Two or three glass tubes, containing 20 grams of charcoal, are connected together by glass tubing, and arranged so that they can be readily heated to 300° C. by means of electric heaters, and the evolved gases completely pumped. When this condition is attained the tubes are immersed in liquid air, and at the temperature of liquid air the charcoal will adsorb nitrogen, hydrocarbons, and other heavy gases, but will not adsorb the helium, provided a sufficiently low vacuum is kept in the tubes. Stopcocks are placed between the charcoal tubes, and it is advisable to have a by-pass between alternative tubes, so that any particular tube can be eliminated from the train, if desired. The gas to be analyzed is run slowly through the train, the stopcocks giving the proper control, and everything but the helium is adsorbed. The latter gas is pumped by a sprengel pump into a graduated tube over mercury and the volume of the helium finally obtained is measured and corrected for pressure and temperature. The purity of the gas can be determined at any time during the analysis by observing the spectrum in a Plücker tube attached between the pump and the last charcoal tube.

Very concordant results can be obtained by this method and the work done up to date by the Bureau of Mines has indicated that the method is extremely satisfactory. If the pressure is allowed to build up too much, some helium is retained by the charcoal, but this is not true at the low pressures actually worked with.

ORIGIN OF HELIUM IN NATURAL GAS.

The origin of helium in natural gas is of great scientific interest. As already stated the origin of helium in the air is generally accepted as due to radioactive changes going on in uranium and thorium minerals in the earth's crust. The origin of helium in natural gas is more difficult to explain. The total amount of helium which has been evolved by the gas wells in the Petrolia field up to the present time is more than sixty million cubic feet. The area of this field is probably not more than eight or ten square miles, with a possible drainage area of forty to fifty square miles.

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[64] *Am. Chem. Soc. Jour.*, Vol. 29, p. 1522.

It is inconceivable to the writer that sixty million cubic feet of helium could be produced by radioactive changes in the earth's crust within this limited area. Two thousand pounds of uranium metal, plus all of its disintegration products in equilibrium, will give 110 cubic millimetres of helium per annum. On this basis it is very easy to calculate how much uranium and what time would be required to give sixty million cubic feet.

Since the total volume of helium liberated in this country is probably as much as three to four hundred million cubic feet per annum, any argument for a radioactive origin has to assume large quantities of uranium or thorium minerals more or less localized. There is no evidence whatever of such deposits, and, therefore, such an explanation is at least unsatisfactory until we have more evidence of the presence of large deposits of radioactive minerals in the earth's crust.

Another explanation is that helium is more or less "primordial" in character, and, therefore, does not have anything to do with radioactive changes. Under this theory the helium might have been brought from the sun at the time the earth was thrown off from the sun. As explained in the early part of this article the chromosphere surrounding the sun consists of hydrogen and helium, and it might be possible for helium to be occluded below the earth's crust from such a source. One of the difficulties of this theory is to explain the more or less localized presence of helium. In addition, if helium in natural gas has such an origin, it should properly contain coronium and other gaseous elements which are known to exist in the sun, and helium derived from natural gas should be the most likely place to look for such new elements. The writer, with the assistance of Mr. Seibel, has already done some work in this connection. We have fractionated the helium obtained from natural gas by adsorption with charcoal under a pressure of 1200 pounds at the temperature of liquid air. Under this pressure, and at this temperature, there is a moderate adsorption of the helium, and this adsorbed helium was purified and a number of photographs made of the spectrum. There were no new lines found in this spectrum, but as it is probable that coronium is not only lighter than helium, but lighter than hydrogen, one would expect to get such a gas in the lighter fractions rather than in the heavier, and the work done up to date simply clears the way for a continuation, using charcoal as a means of purification. The writer desires to express his cordial thanks to Professor Frost, of the Yerkes University, for his kindness in checking up the wave-lengths on one of the plates obtained.

The following gives the wave-lengths of unknown lines in the corona. In this table C stands for coronium, and P for protofluorine. The 5303.1 line in the green is the principal coronium line. Great care must be taken in attempting to recognize this line, owing to the fact that there is a secondary hydrogen line very close to it.

TABLE.

*Coronal Bright Lines. Campbell and Moore (1918).**

Mean λ.	Int.	Length minutes of arc.	All observers.		Nicholson's formulæ.
			Probable λ.	Int.	
....	....	....	3288?	Faint	P
....	....	....	28.2	Fairly strong	P
....	....	....	57	Faint	....
....	....	....	88	Very strong	P
....	....	....	3455	Strong	P
....	....	....	61	Faint	....
....	....	....	3505	Faint	P
....	....	....	34	Faint	C
3601.3	5	4½	3601.3	Pretty strong	P
....	....	....	26	Faint	P
41.4	2	1.3	41.4	Rather faint	....
43.1	2	1.3	43.0	Rather faint	C
48.0	2	1.3	48	Rather faint	......
** 51.8	1	....	51?	Faint	....
3801.4	1	2 ±	3801.0	Rather faint	P
....	....	....	65?	Faint	P
....	....	....	91	Faint	P
3986.9	1	2.5	3986.9	Fairly strong	P
4085.9	1	4 ±	4086.0	Fairly strong	P
....	....	....	4130	Faint	....
4231.4	3	6	4231.4	Fairly strong	P
4240.8	1	3 ±	40.8	Faint	......
44.8	1	3 ±	44.8	Faint	....
....	....	....	4311	Faint	P
....	....	....	4359	Rather faint	C
**4397.4?	1	....	98?	Very faint	P
4533.5	2	2 ±	4533.4	Faint	......
** 67.4?	1	....	67	Rather faint	C
....	....	....	86	Rather faint	P
....	....	....	4722?	Faint	P
....	....	....	25	Faint	P
**4778.6?	1	....	79	Faint	....
....	....	....	5073	Faint	P
....	....	....	5118	Faint	P
5303.0	10	4½	5303.1	Very strong	C
....	....	....	5536	Faint	P
....	....	....	6374.2	Strong	C

* *Pubs. A. S. P.*, 30, 350, 1918. ** Measured only by Moore.

If the two above explanations are not correct, it is necessary to accept more radical theories.

Rutherford has shown that if the velocity of the alpha particle drops below a certain minimum, the alpha particle will not ionize gases. This means that an element might be radioactive and give off alpha particles of low velocity, and our present methods of recognition of radioactivity would not be adequate to determine that the particular element in question was changing. The radioactivity of common elements, therefore, has been a question that has received some attention and some thought. Its importance has been accentuated by the presence of helium in certain non-radioactive minerals, and also the work of Strutt, who has shown, as pointed out in the early part of this article, that the Stassfurt potassium minerals contain helium in a quantity out of all proportion to the amount of radioactive material present. Are changes going on in nature about which we know nothing, and are these changes as radical and as important as radioactive changes about which we knew nothing twenty-five years ago? A study of the origin of helium in natural gas is of the greatest importance, as such a study may lead to something more than a mere geological discussion. All of the rare gases are found in some of the natural gases: argon, neon, krypton, and xenon are all present, although the percentages at present are uncertain.

COMMERCIAL STORAGE OF HELIUM.

From the financial standpoint the storage of helium is important. At the present time the government has at Fort Worth about one hundred thousand cylinders holding approximately 200 cubic feet each. The value of these cylinders is over two million dollars and the up-keep is considerable. Serious consideration of other methods of storage is, therefore, important.

It has been suggested by Mr. J. O. Lewis and Mr. G. S. Rice, of the Bureau of Mines, that helium might be stored after extraction in concrete chambers in mines. The suggestion is to build a concrete chamber in a drift, with reinforced concrete ends, and a manhole, the whole to be lined with sheet copper to prevent loss of the gas through the concrete. The gas would be stored under a pressure of 400 or 500 pounds, and the walls of the drift would take most of this pressure, so that the thickness of the concrete would necessarily be small, and largely required for getting a smooth surface for the copper sheeting.

A good location probably would be in the St. Peter's sandstone in the Mississippi Valley, where the sandstone outcrops at the surface, and a long tunnel could be driven into the sandstone of the proper diameter and length. Under such conditions a chamber 400 or 500 feet long, and 6 or 8 feet in diameter, might be constructed and lined with copper or sheet lead. It is estimated that the cost of such storage per annum might be as low as from one-tenth to one-fifth of a cent per cubic foot.

It has also been suggested that helium might be stored in some of the salt deposits of New York. In this State some of the rock salt deposits are 60 feet thick and covered with a fairly heavy overburden. By drilling into the salt, and flushing out with a stream of water, a circular cavity could be made in the salt with a long neck, such cavity being 40 or 50 feet in diameter. The chamber would be something like a bottle with a very long neck, and helium might be stored in such a chamber under pressure satisfactorily. A series of "bottles" could be placed close together in the same deposit. It is necessary, of course, to know whether helium does or does not diffuse through salt in order to apply such a scheme practically, and this diffusion work is now being done by the Bureau of Mines.

The storage in a concrete chamber is being tried out at the experimental mine of the Pittsburgh Station of the Bureau, and it is expected that the practicability of this method can be determined shortly.

CRYOGENIC LABORATORY.

A very considerable amount of scientific data is still needed for the proper and efficient operation of the helium plants. Practically no work has been done in the past on vapor pressures, specific heats, or heats of vaporization of mixtures of helium, nitrogen, methane, and the other hydrocarbons, and yet the efficient operation of the plants is very largely dependent upon data of this character. This was recognized by the Bureau of Mines quite early, and some preliminary work was done at the Bureau of Standards by Messrs. Simpson and Osborne. Last year arrangements were made with Dr. Harvey N. Davis, of Harvard University, and Dr. F. G. Keyes, of Massachusetts Institute of

Technology, to do further work along this line, and this is now in progress. There is, however, a distinct advantage in having a thoroughly equipped laboratory which is available at all times for research work in connection with the plants, and this has been accomplished through the establishment this year in the Bureau of Mines at Washington of a cryogenic laboratory under the direction of the writer. Through the interest and broadmindedness of Commander A. K. Atkins, of the Navy, and Colonel C. DeF. Chandler and Lieutenant R. S. Olmsted, of the Army Air Service, the necessary funds for the purchase of equipment and the present maintenance of this laboratory were furnished to the Bureau of Mines late last spring. The equipment is now being installed in the new Department of Interior Building at Washington. It consists of two 4-stage Norwalk compressors with a capacity of 75 cubic feet of free air per minute each. These will be used for making liquid air and for other purposes in connection with the experimental work. There will also be one vertical submarine type Norwalk compressor with a capacity of 12 cubic feet of free air per minute, to be used in connection with the liquid hydrogen cycle, and a similar compressor with a capacity of 8 cubic feet of free air per minute for use in connection with a liquid helium cycle. These compressors will all be driven by variable speed motors, and be equipped with unloading valves, so that the capacities can be varied within wide limits. In addition there will be an adequate equipment of gas holders, a machine shop, and a chemical and physical laboratory. The force will consist of Mr. J. W. Davis, mechanical engineer, of Yale and Stanford Universities; Mr. C. W. Seibel, physical chemist, of Kansas University; Dr. Leo Finkelstein, physical chemist, of the University of Chicago, and Dr. A. G. Loomis, physical chemist, of the University of Missouri. In addition, there will be an engineer and a mechanic available.

Whereas the main object of the laboratory will be to assist in every possible way the whole helium project, both on the production and refining ends, there is a strong desire that this laboratory shall be of material use to science in general, and that it may be possible later on to make arrangements for its facilities to be used in special cases by men outside the government service who are specially equipped for such work. There are a number of laboratories in the country that have liquid air machines. There are three or four that have equipment for making liquid hydrogen, although up to date liquid hydrogen has only been made once or twice in this country in very small quantities. There is no laboratory outside of the one just described that has equipment for liquefying helium.

The writer desires to acknowledge the coöperation of the Army and Navy officials who have been connected with the helium work. A number of these have been mentioned in the course of this article. At the present time Lieutenant Commander Kraus represents the Navy and Major P. E. Van Nostrand the Army. Both of these gentlemen fully appreciate the importance of the work, and are bending every effort to make it a complete success.

Nitre Cake.—H. T. CALVERT and E. H. MORRIS describe the production and uses of nitre cake in Great Britain during the Great War (*Journal of the Society of Chemical Industry*, 1920, xxxix, Review, 408–411). Nitre cake is an acid sodium sulphate; it is produced in the nitre pots at sulphuric acid works, and in the retorts in which sodium nitrate and sulphuric acid are heated for the manufacture of nitric acid. Its acidity, calculated as sulphuric acid, may be as low as 28 per cent. or as high as 33 per cent., with an average of 30 per cent. During the war, the amount produced in nitre pots increased but 50 per cent. over the pre-war normal, while the amount produced in the manufacture of nitric acid increased 2000 per cent. The increased use of sulphuric acid for the manufacture of nitric acid for explosives greatly decreased the supply of the former acid available for industrial purposes. However, since large amounts of nitre cake were being produced, it was used in the arts in place of sulphuric acid. During the first ten months of 1918, the average monthly production of nitre cake was 27,500 tons, and the average monthly consumption 22,500 tons, or over 80 per cent. of the amount produced. Among the industries using nitre cake were: Grease recovery, bleaching and dyeing, metal pickling and cleaning, manufacture of hydrochloric acid, production of carbonated waters, glue, fertilizer, glass, alum manufacture, and some dozen other trade processes. In November, 1918, over 1000 railroad cars were in use for the transportation of nitre cake. The cake was drawn from the retorts into shallow cast-iron trays, permitted to solidify, and then broken into pieces of suitable size. Granulated nitre cake was obtained by rabbling the molten mass in rabbling pans, or by forcing a current of compressed air upon a falling stream of the molten mass, whereupon the nitre cake congealed as small pellets. Solutions of nitre cake in water were also placed on the market in carboys. J. S. H.

Foreign Zinc Industry in 1920. (*U. S. Geological Survey Note,* January, 1921.)—Of the European zinc-producing centres Belgium and Upper Silesia seem to be in the best condition. Belgium started the year with a smelter output of about 4500 short tons monthly, which it brought up by the middle of the year to 8000 tons. After that the output remained about stationary, so that the total production for the year was probably about 90,000 short tons. Reports near the end of the year indicate that the output is slackening and considerable stocks are on hand. The total stocks in Europe are thought to amount to 100,000 short tons. Belgian smelters have recently contracted for a supply of Australian zinc concentrates. The zinc output of smelters in Upper Silesia in 1919 was 81,596 short tons, equal to about 60 per cent. of the production in 1918. Reports for the first half of 1920 indicate a little larger production than in 1919, the output for the six months being 49,643 short tons. The zinc industry in other European countries and in Japan is reported at a low ebb. Perhaps the most noteworthy happening in the zinc industry during the year was the acquisition of the Mount Read and Roseberry mines, Tasmania, by the Electrolytic Zinc Co. of Australasia, by which that company gains immense reserves of ore. The enlargement of the electrolytic zinc plant at Risden, near Hobart, Tasmania, continues, a zinc rolling mill and a zinc oxide plant having been installed.

Positive Ray Analysis of Magnesium. A. G. DEMPSTER. (*Science,* December 10, 1920.)—It is not only in Europe that isotopes are being discovered by means of positive ray analysis. The announcement comes that in the Ryerson Physical Laboratory of the University of Chicago three isotopes of magnesium have been detected of atomic weights 24, 25, and 26, respectively. The rays from the 24 isotope are about six times as strong as the others, which are of equal intensity. This relation gives for the average atomic weight 24.375, which is not far from the accepted atomic weight 24.36.

The *Revue Générale des Sciences* for October 30, 1920, has an excellent article on this method of chemical analysis, written by Mlle. S. Veil.

G. F. S.

Improved Gunnery in the Navy. (*Scientific Am.,* December 11, 1920, p. 589.)—Analysis of the gunnery exercises of the American Navy during the past year shows that the greatest progress toward efficiency was made by vessels of the battleship class, due to the larger number of men aboard such ships and the comparative stability of the personnel. The Navy Department considers that battleship gunnery is at present about equal to that of foreign battleships. It is believed that next year vessels of other classes will be brought up as regards gunnery to the level of our battleships.

THE DETERMINATION OF THE STRUCTURE OF CRYSTALS.*

BY

RALPH W. G. WYCKOFF, Ph.D.,

Geophysical Laboratory, Carnegie Institution of Washington.

INTRODUCTION.

THE following discussion aims to give a brief survey of the field of the determination of the structures of crystals as it exists at the present time. The most essential events in the development of this work are mentioned, the existing means of experimentation are outlined, and some of its present limitations are discussed together with some of the kinds of problems to which a knowledge of the arrangement of the atoms in crystals has contributed and may be expected to contribute.

AN OUTLINE OF THE DEVELOPMENT OF THE MEANS EMPLOYED IN STUDYING THE STRUCTURES OF CRYSTALS.

The Experiment of Laue.—For some time it has been evident that the distance apart of the atoms in a solid body is of the order of 10^{-8} cm.[1] In the days before the nature of X-rays was known, attempts were made to see if they could be diffracted by passage through very narrow slits; the results of these experiments showed that if X-rays really were wave motions of a nature similar to ordinary light, their wave-lengths could not by much exceed 10^{-9} cm.[2]

Starting from this information Laue concluded that if X-rays are wave motions of this type they should be diffracted on passing through an orderly arrangement of atoms such as is furnished by a crystal; and, as a matter of fact, when a narrow pencil of X-rays was passed through a thin section of a crystal, a number of diffracted images of the pinhole defining the beam were obtained, arranged in a symmetrical fashion about an undiffracted

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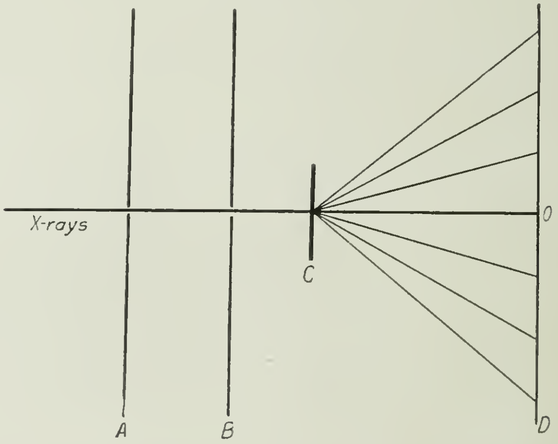
* Communicated by Dr. Arthur L. Day, Director of Laboratory, Associate Editor.

[1] An indication of the dimensions of the "spheres of influence" of atoms has been obtained in many ways, as from the thickness of soap-bubble films, from calculations based on the kinetic theory of gases, and more especially from the work of Perrin on the Brownian movement and from counts of α – particles.

[2] B. Walter u. R. Pohl: *Ann. d. Phys.*, 25, 715, 1908; 29, 331, 1908. R. Sommerfeld: *Ibid.*, 38, 473, 1912. P. P. Koch: *Ibid.*, 38, 507, 1912.

image.[3] The arrangement required for carrying out this experiment is shown in Fig. 1. A beam of X-rays after passing through two pinholes in the lead screens *A* and *B* proceeds through the thin section of a crystal at *C* and registers itself as the undeviated and diffracted images upon a photographic plate placed at *D*. The kind of diffraction patterns that are thus obtained are shown in Figs. 2 to 9.[4] Their symmetry is seen to be directly related to the symmetry of the diffracting crystal; for instance, the cubic crystal of magnesium oxide gives a fourfold pattern (Fig. 9) when the X-rays pass along a tetragonal axis, a trigonal crystal such as calcite furnishes a pattern (Fig. 7) that shows a threefold symmetry when the X-rays are travelling parallel to the principal axis.

FIG. 1.



The "Reflection" of X-rays.—In Laue's experiment the crystal may be thought of as behaving toward X-rays as if it were a three-dimensional diffraction grating. The mathematical treatment of such a grating[5] presents very considerable difficulties. Fortunately, however, W. L. Bragg has pointed out that these diffractions of X-rays by the atoms of crystals can just as satisfactorily, and vastly more simply, be treated as *reflections* from *planes of atoms* within the crystal.[6]

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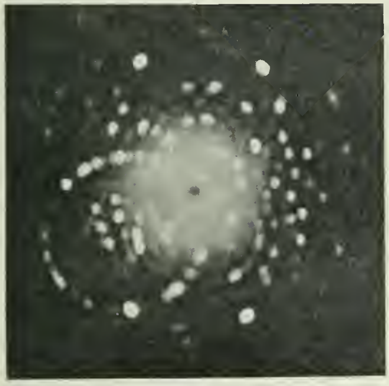
[3] M. Laue, W. Friedrich, u. P. Knipping: *Ann. d. Phys.*, 41, 971, 1913.

[4] Figs. 2 and 3 are obtained from photographs by F. Rinne, *Ber. Verh. K. Sächs. Ges. Wiss.*, 67, 303, 1913. The others have been prepared by the writer.

[5] M. Laue, W. Friedrich, u. P. Knipping: *Op. cit.*

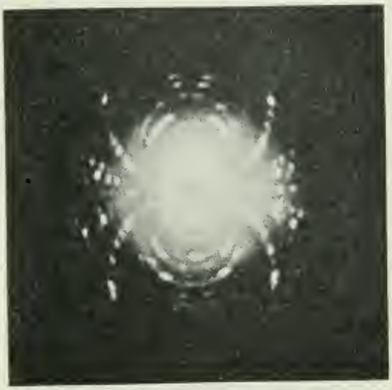
[6] W. L. Bragg: *Proc. Camb. Phil. Soc.*, 27, 43, 1913.

FIG. 2.



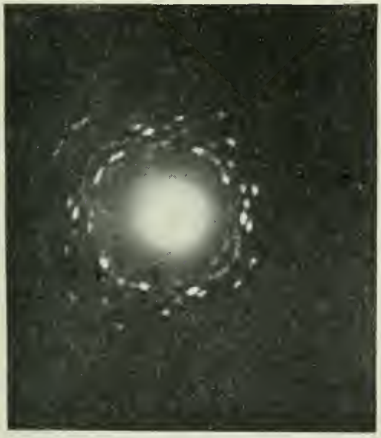
Cyanite. Triclinic. X-rays normal to the (100) face.

FIG. 3.



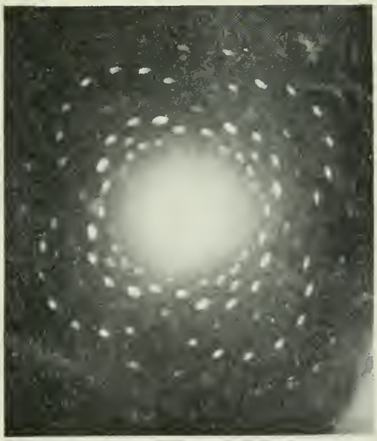
Skolezite. Monoclinic. X-rays normal to the (100) face.

FIG. 4.



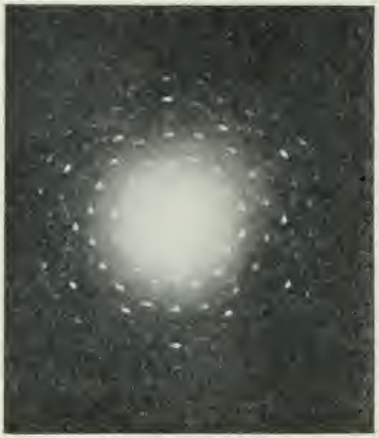
Potassium sulphate. Orthorhombic. X-rays normal to the (001) face.

FIG. 5.



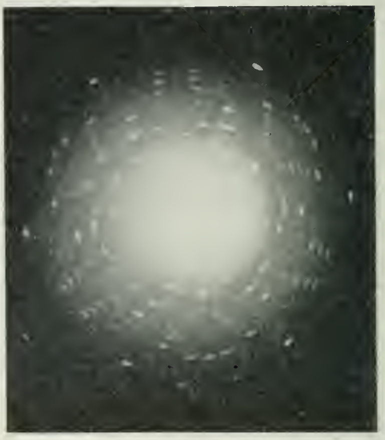
Rutile. Tetragonal. X-rays normal to the (001) face.

FIG. 6.



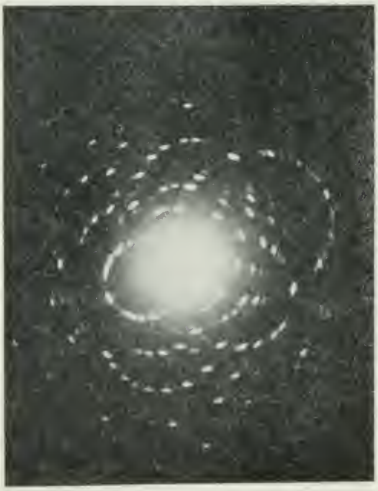
Carborundum twinned to give an hexagonal pattern. X-rays normal to the (0001) face.

FIG. 7.



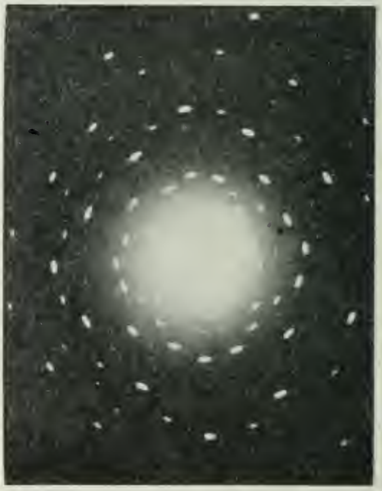
Calcite. Rhombohedral. X-rays normal to the base (111).

FIG. 8.



Calcite. Rhombohedral. X-rays normal to the cleavage (100) face.

FIG. 9.



Magnesium oxide. Cubic. X-rays normal to the cube (100) face.

This point of view suggests that X-rays ought to be "reflected" from the faces of crystals. If a parallel beam of X-rays of a single wave-length strikes the face of a crystal mounted at C (Fig. 10), it is found that X-rays are reflected at certain definite angles.[7] The mechanism of this "reflection" has an optical analogue: if a beam of light falls upon a stack of thin plates of transparent material such as glass, this light is found to be reflected strongly only at definite angles, the values of which will depend partly upon the wave-length of the incident light and the distance apart of the reflecting surfaces. These plates of glass may be taken as corresponding to the planes of atoms in the crystal.

The factors governing the reflection of X-rays can be shown with the aid of Fig. 11.[8] The reflecting planes of atoms parallel to a crystal face are represented by $p, p_1 \ldots p_n$; the beam of X-rays $A, A_1, \ldots A_n$ strikes the face of the crystal at the angle θ; the distance between the planes of atoms is d. The following conditions will govern the reflection of the X-rays along the direction BC. Draw BE perpendicular to A_1B_1 and BD perpendicular to the planes $p, p_1, \ldots p_n$. The difference in path between the ray ABC and A_1B_1C is

$$BB_1 - B_1E.$$

When this difference is exactly equal to a whole number of wave-lengths of the X-rays, the beam which is reflected from the plane p_1 will arrive at C exactly in phase with that reflected by the plane p; otherwise it will suffer practically complete neutralization by reason of the various sorts of phase relationships which exist between the reflections from the different planes of atoms. Consequently, in order that there may be a reflection of the X-rays along the direction BC, it is necessary that

$$BB_1 - B_1E = n\lambda,$$

where λ equals the wave-length of the X-rays and n (called the "order" of reflection) gives the number of whole wave-lengths difference in path of the reflected X-rays. In the triangle BB_1D the side BB_1 = the side B_1D so that $BB_1 - B_1E = ED$. Therefore,

$$ED = n\lambda.$$

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[7] See W. H. and W. L. Bragg: "X-rays and Crystal Structure." London, 1918.

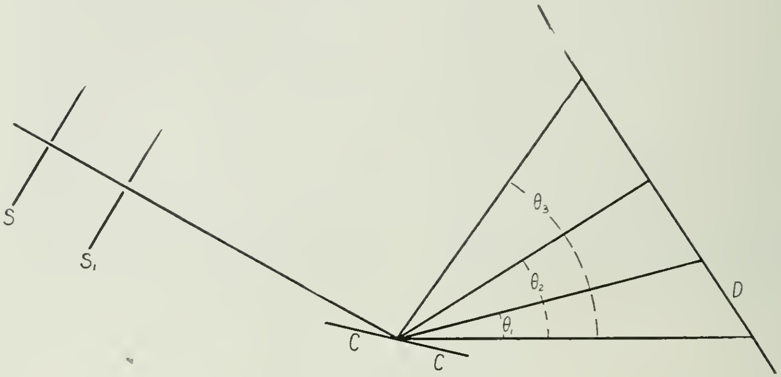
[8] W. H. and W. L. Bragg: *Op. cit.*, Chap. ii.

Now the angle DBE = the angle $ABp = \theta$; and $BD = 2d$. From this

$$ED = 2d \sin \theta = n \lambda. \tag{1}$$

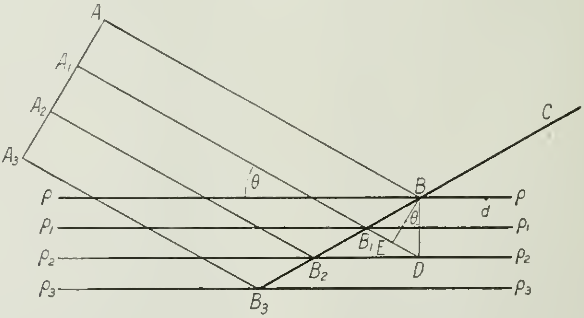
This is the fundamental equation underlying all reflections of X-rays.

FIG. 10.



Powder Reflections.—It has just been seen that diffraction, or "reflection," effects with X-rays result either from passing them through a thin section of a crystal (the Laue experiment) or by "reflecting" them from the face of a crystal. In both of these cases a single crystal of considerable size and perfection is required. There is one other way in which definite diffraction can be obtained: by "reflecting" the X-rays from a haphazard arrangement of crystals such as is furnished by a fine powder.[9]

FIG. 11.



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[9] P. Debye u. P. Scherrer: *Phys. Z.*, 17, 277, 1916. A. W. Hull: *Phys. Rev.* 10, 661, 1917.

In such a completely chaotic grouping of crystalline particles some of them will be in a position to reflect X-rays from each important crystal plane. Thus interference effects from all of the possible planes in the crystal will be produced at the same time. This third method of obtaining diffraction effects makes available for study the large group of substances which can not be obtained as crystals of appreciable size.

The Structure of Sodium Chloride.—The reflection of X-rays by crystals gives a means of obtaining information about the arrangement of the atoms in the crystal. If the structure of a crystal is known, then the wave-length of X-rays can be determined. From equation (1) it is seen that if X-rays of the same wave-length are employed, the relative distance apart of like planes of atoms in different directions can be derived from a measurement of the angles of reflection. From such measurements it appears that the spacings of like planes normal to the cube, dodecahedral and octahedral, (100), (110) and (111), planes of sodium chloride stand in the ratio of

$$1 : \frac{1}{\sqrt{2}} : \frac{2}{\sqrt{3}} .$$

W. H. and W. L. Bragg pointed out [10] that these observations can be accounted for if the atoms of sodium chloride have the positions shown in Fig. 22 (see page 223).

The Wave-lengths of X-rays.—A knowledge of the arrangement of the atoms in any crystal makes possible a determination of the absolute length of X-rays. The necessary procedure is somewhat as follows: A crystal may be imagined as made up of a vast number of units of structure, all alike in size and shape and similarly oriented; for instance a cubic crystal will be divisible into cubes, a hexagonal crystal into either hexagonal prisms or rhombohedrons, and so on. Fig 22 shows such a unit for the structure assumed for sodium chloride. That four chemical molecules are associated with this cube will be clear from the following considerations. The eight sodium atoms at the corners of the unit are each shared by eight cubes; all of them thus place within the unit the equivalent of the mass of a single sodium atom. The atoms N and P are each shared by two cubes; both together then supply another sodium atom within our cube. The two remaining sodium atoms are furnished by L and M and by Q and R. In a similar fashion it can be shown that four chlorine atoms are associated with this unit.

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[10] W. H. and W. L. Bragg: *Op. cit.*, Chap. vii.

The volume of the cube can be written:

$$V = \frac{mM}{\rho}$$

where

V = the volume,
m, the number of molecules of sodium chloride within the unit, = 4,
ρ, the density of sodium chloride, = 2.17,
M, the mass of a single molecule of sodium chloride, equals the molecular weight multiplied by the weight of an atom of hydrogen, = $58.5 \times 1.64 \times 10^{-24}$ grams.

From these, d, the length of a side of the cube, $\sqrt[3]{V} = 5.60 \times 10^{-8}$ cm. If the reflection is taken from the face *CDHG*, then the distance d between like cube planes is the distance between the plane *CDHG* and the plane *BAEF*. The reflection from planes of such a spacing would be of the first order. But it will be seen that the plane *QLRM* has exactly the same composition as these other two planes and is spaced midway between them. The waves reflected from it will then be exactly out of phase with those from the other planes and, having the same amplitude, will blot them out completely. The first reflection to be found from the cube face of this arrangement of atoms is thus of the second order. If X-rays from a tube having a palladium target are used, the angle of this reflection is found to be 5.9°. In equation (1) we now have

$$n = 2,$$
$$d = 5.60 \times 10^{-8} \text{ cm},$$
$$\theta = 5.90^\circ.$$

Consequently λ is equal to 0.576×10^{-8} cm.[11]

The obvious objection to this determination lies in the fact that though this particular structure for sodium chloride agrees with the experimental data just mentioned, there may be, for aught it tells, a myriad of other structures which are in equally good agreement. The large amount of data, however, agreeing with this structure and the value of the wave-length of X-rays derived from it that has since been obtained from different sources makes their truth seem highly probable.

Using this same method of procedure, W. H. and W. L. Bragg and others have found structures which will account for the positions of the reflections from the most important faces of a number of crystals, such as sodium and potassium chlorides, iron pyrites, the diamond, carborundum, and various members of the calcite group of minerals.[12] Probably in no case can the structures which are *thus* obtained be said with absolute surety to correspond with the arrangements of the atoms within these crystals.

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[11] W. H. and W. L. Bragg: *Op. cit.*, Chap. vii.

The General Method of Studying the Structure of Crystals.—It consequently becomes necessary, if we are to make any definite and certain progress toward unravelling the structures of crystalline compounds, that a method be developed which will make it possible to determine *uniquely* such structures, or at least that will indicate the degree of probability with which a particular structure has been determined. Fortunately the basis for such a method was already prepared, for the geometrical theory of space groups developed many years ago by Federov, Schönflies, and Barlow can be made to give *all* of the possible ways of arranging points in space so that the grouping which results will exhibit crystallographic symmetry.[13] Since a crystal is an orderly arrangement of atoms in space, it must correspond with one of these space groups. Consequently when the space groups are given a suitable analytical representation, a means quite independent of any X-ray experiments is provided for writing down *all* of the possible positions which the atoms of *any* compound can occupy. After this has been done the particular data which will serve to distinguish between these various possible arrangements can be selected and those methods of experimentation employed which will yield most readily the needed facts. Such a method has the advantage of being equally applicable to complicated and to very simple structures. The point of view involving such a use of the theory of space groups was used first by Nishikawa in studying spinel.[14] The geometry of the method arising from it, which has been in the course of development for several years,[15] may now be said to be nearly completely developed.

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[12] W. H. and W. L. Bragg: *Op. cit.*, Chaps. vii and viii. C. L. Burdick and E. A. Owen: *J. Am. Chem. Soc.*, 40, 1749, 1918; C. L. Burdick and J. H. Ellis: *Ibid.*, 39, 2518 (1917); R. G. Dickinson: *Ibid.*, 42, 85 (1920); and others.

[13] E. Federov: *Z. Kryst.*, 24, 209, 1895. A. Schönflies: "Krystallsysteme u. Krystallstruktur" (1891). W. Barlow: *Z. Kryst.*, 23, 1, 1894.

[14] S. Nishikawa: *Proc. Tokyo Math. Phys. Soc.*, 8, 199, 1915.

[15] This development has been going on independently in Germany and in this country. For instance, see P. Niggli: "Geometrische Krystallographie des Discontinuums" (1919); Ralph W. G. Wyckoff, *J. Am. Chem. Soc.*, 42, 1100, 1920; *Am. J. Sci.*, 50, 317, 1920; *Ibid.*, 1, 127, 1921.

THE METHODS OF OBTAINING DIFFRACTION EFFECTS FROM CRYSTALS.

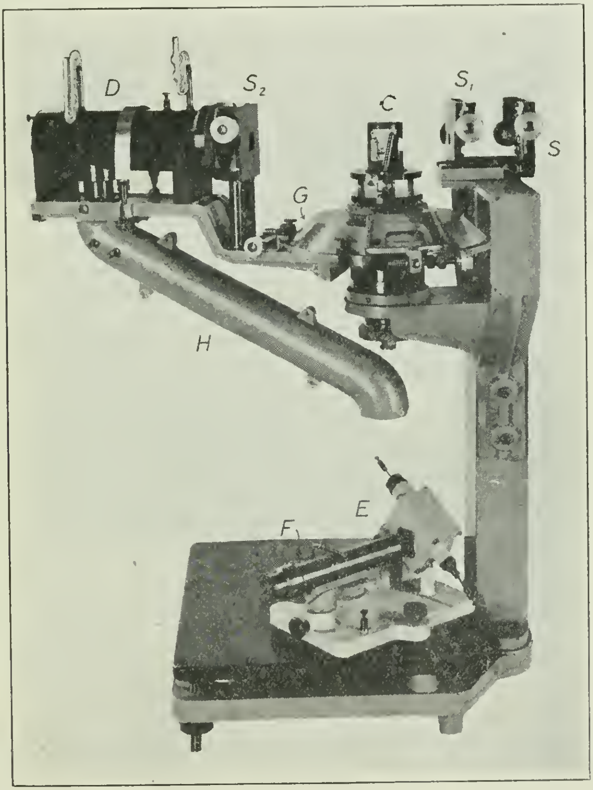
The Spectrometer Method.—Three ways of obtaining definite X-ray diffractions have been mentioned: (1) by reflecting X-rays from individual faces of a crystal; (2) by reflecting them from a crystalline powder so that all of the possible crystal planes have an equal chance to reflect; (3) by passing X-rays through a thin section of a crystal. We shall now discuss very briefly the way in which these three kinds of experiments are carried out and point out the kinds of data that can be obtained from each.

The first of these diffraction methods may be called the spectrometer method. X-rays, preferably of a single wave-length, are passed through two narrow slits of an X-ray spectrometer in order to render them parallel; this beam, after reflection from the face of a crystal mounted upon the spectrometer table, passes into an ionization chamber, where its intensity is measured by the magnitude of the ionization which it produces in the gas of this chamber. Such an X-ray spectrometer is shown in Fig. 12. The X-rays passing from an X-ray tube through the slits S and S_1 strike the face of the crystal mounted at C. When the ionization chamber D and the crystal C stand at the proper angles, the reflected beam of X-rays enters the chamber D through a mica window by way of the slit S_2. This chamber is filled with some gas, usually sulphur dioxide or, better, methyl bromide, which ionizes strongly under the action of X-rays.

The case of the ionization chamber is charged to a potential of about 200 volts, while the inside insulated electrode, which is connected only with the gold leaf of a sensitive electroscope E, is, at the moment of beginning the experiment, at the potential of the ground. As X-rays enter the chamber and ionize the gas within it, the potential of the gold leaf will change. The rate of this change is measured by the drift of the gold leaf and taken as an indication of the intensity of the reflected X-rays. By properly adjusting the positions of the crystal and of the ionization chamber, the relative intensities of reflection from a single face can be obtained for the various orders. This information is usually sought for several faces of a crystal.

In place of an ionization chamber and electroscope for measuring the diffracted X-rays a photographic plate can be used. If the X-rays are of a single wave-length an image of the slit will appear at the position conditioned by equation (1). If the X-rays in the original beam are of more than one wave-length, as is usually the case, then for a perfectly constructed crystal—meaning thereby one in which the atoms are arranged with perfect regularity throughout the entire mass—and for perfectly parallel X-rays, only the image corresponding to one wave-length will appear upon the photographic plate for a particular orientation of the crystal.

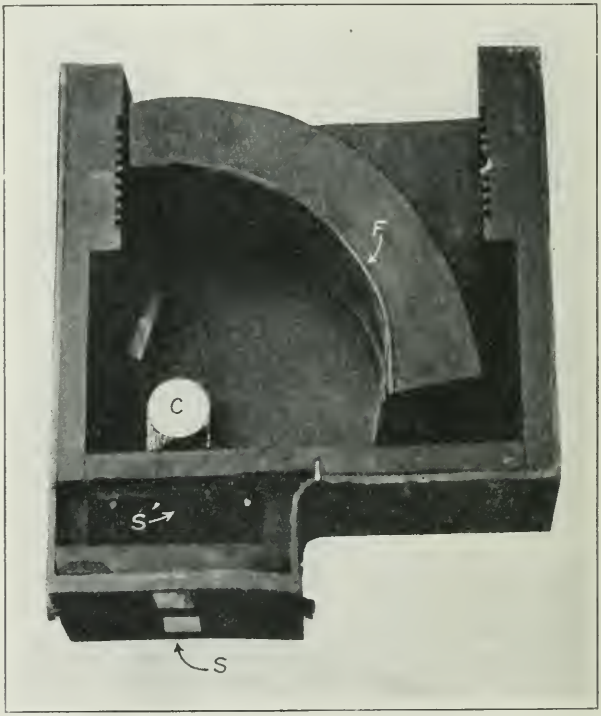
FIG. 12.



An X-ray spectrometer. *G* is a divided circle upon which the positions of the crystal and ionization chamber may be read; *F* is a microscope and scale for following the gold leaf of the electroscope (*E*); *H* is an earthed shield for the wire connecting the chamber and the electroscope.

If the beam of X-rays is slightly divergent after passing through the slit of the spectrometer, it can be shown from geometrical considerations that the X-rays of somewhat different wave-lengths which can thus be reflected will focus upon a surface which is as far from the crystal as the crystal is distant from the slit. This fact is of utmost importance in designing an X-ray spectrograph. If a photographic film is curved to the arc of a circle of a radius equal to the distance from the crystal to the slit, and whose centre is at the crystal face, then a focused image of a small range of wave-lengths will appear upon the film. Furthermore, if the crystal is but rotated continuously back and forth, all of the different wave-lengths in the original beam will be reflected at some angle of the rotating crystal. A photographic image of the entire X-ray spectrum can thus be obtained. Fig. 13 shows a spectrograph designed for obtaining such reflections. Fig. 15 (page 215) gives the X-ray spectrum of tungsten obtained in the manner just outlined.

FIG. 13.



The front slit (*s*) is variable. The second one (*s'*) is fixed at a considerable width so that the beam of X-rays striking the crystal mounted on the rotating table (*C*) is somewhat divergent. The photographic film is curved to the arc of a circle along *F*.

Spectrometer Data.—The principal use of the photographic

X-ray spectrometer (spectrograph) in studying the structure of crystals lies in determining the absolute distances apart of like planes in some one direction in the crystal. This information, furnishing a knowledge of the number of molecules to be associated with the unit of structure, is the first piece of experimental data that is required in studying the structure of a crystal. It can be obtained much more readily by photographic means than by searching about looking for a reflection, as must be done if the spectrometer itself is employed to give the same information.

The following is an outline of the nature of the data which the spectrometer and the spectrograph can be expected to yield. It has just been stated that the number of chemical molecules associated with the unit of structure can be deduced from a knowledge of the position of the reflection from a single face of a crystal. The procedure required to give this information is quite the same as that already used in getting the wave-lengths of X-rays. Equation (1), $n\lambda = 2d \sin\theta$ can be written: $d = \frac{n\lambda}{2 \sin \theta}$. It has been indicated that

$$V = \frac{mM}{\rho}. \tag{2}$$

$$V = c(d_{100})^3 \tag{3}$$

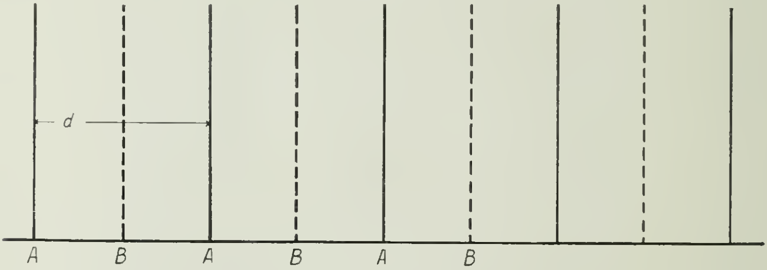
where d_{100} is the spacing in the direction of the side of the unit prism and c is a constant whose value is determined by the symmetry of the crystal (and is obviously equal to unity in the case of a cubic crystal). By combining (2) and (3): $m = \frac{c(d_{100})^3 \rho}{M}$; substituting the value of d obtained by equation (1), there results:

$$\frac{m}{n^3} = \frac{c\lambda^3 \rho}{8 \sin^3 \theta M}.$$

Besides telling the absolute distances apart of the planes of atoms in the crystal, spectrometer measurements give some indication of the composition of these planes. Imagine that the atoms of a certain crystal are so arranged that in a direction normal to some face they lie in planes spaced as in Fig. 14. The distance apart of like planes of these atoms is d; but midway between the planes made up of atoms of A are planes of atoms of B. The waves reflected from the A planes and from the B planes will interfere to an extent which depends upon the relative reflecting powers of these atoms. If, for example, the reflecting power of atom A were just equal to that of atom B, it is then quite clear that the first order reflection from one kind of plane, being of exactly opposite phase to that from the other, would just nullify the reflection from this other plane so that the distance apart of like planes would seem to be half of what it really is. If the reflecting powers of the two atoms were not equal, then there would still appear a first order reflection, but one weakened to an extent dependent upon the difference in the scattering powers of the two kinds of atoms.

The "Laws" of Reflection.—The use of this kind of information in deciding the arrangement of atoms in a compound necessitates that the relative reflecting powers for X-rays of the different atoms be known. Previous studies of their scattering powers made it appear that atoms scatter and reflect X-rays in an amount very roughly proportional to their atomic weights, or, more correctly perhaps, their atomic numbers. The reflections from various crystals seem to have confirmed this rough proportionality; but whether the "reflecting" power is strictly proportional to the number of electrons in the atoms, and if not, what may be the exact nature of the function expressing their scattering powers, is at present unknown.

FIG. 14.



It has been stated that the use of the spectrometer makes possible the estimation of the relative intensities of the reflections from various crystal faces in the different orders. We have already seen how the intensity of reflection can be taken as an indication of the composition of the reflecting planes. But in order to do this it is obviously necessary to know the normal distribution of intensity in the different orders, or, what amounts to the same thing, to know how the intensity of reflection depends upon the spacing between like planes of atoms in a crystal. The form of this function is not known now with any degree of certainty.

Until a knowledge of these two factors governing the amount of reflection of X-rays—the effect of atomic number and the effect of spacing—is available, it is useless to attack by the means we have been discussing any but the simplest of crystals. Even with these it is never certain that the structure selected as agreeing with the experimental data is actually the correct one. It may be urged that if a lack of knowledge of these two " laws " of reflection is the only thing that delays the determination of the structures of many and complicated crystals, then we should immediately proceed to discover the forms of these two expressions. The reason for not carrying out this apparently simple program is not hard to find. The commonly employed spectrometer method of studying the structure of crystals involves the simultaneous use of these " unknowns "; only in relatively few instances has it been possible to get at the arrangement of the atoms in a compound without assuming values for both of these expressions. Since it is only by working with crystals whose structures are known with certainty that progress can be made toward a satisfactory solution of these two problems, and since a use of the answers to these same problems are usually involved in getting the structures themselves, advancement has not been made.

These two " laws " which we have been discussing are of very considerable importance quite aside from their use in the determination of the structure of crystals. Such meagre information as is at present available seems to show conclusively that the forms they will take can only be accounted for by taking into consideration the intimate structure of the atoms themselves.

The diffraction or reflection of X-rays by an atom may be roughly pictured as follows: When a beam of X-rays of definite wave-length strikes an atom the rays may be supposed to accelerate the electrons contained within this atom. X-rays which are emitted by such electrons are the diffracted (scattered or reflected) radiation. If all of the electrons in an atom were concentrated very close to the centre the amount of scattered X-rays should be quite closely proportional to the number of electrons in the atom. Such a proportionality is in reality only very roughly fulfilled; in fact, some of the evidence seems to point to quite marked variations from it. This lack of proportionality is most simply and easily explained by supposing that the atom, meaning thereby the volume occupied by the electrons surrounding the atomic nucleus, is relatively large. The X-rays scattered by electrons on one side of the atom will interfere, sometimes destructively and sometimes constructively—depending upon the absolute magnitude of the atom itself and upon the wave-length of the X-rays—with those rays scattered by electrons on the opposite side of the atom. This idea of atoms of appreciable size almost certainly must be called into play in order to account for the peculiar way in which the intensity of reflection varies with the angle of reflection.

This field of studying the intimate structure of the atom is quite untouched at the present time. The results which are to be obtained from it are, as we have seen, of more or less doubtful value until the determination of the structure of crystals has been put upon a very certain basis. When this has been done, that is, when we have succeeded in determining *uniquely* the structures of a few crystals, these methods of X-ray experimentation can quite properly be expected to yield very useful information.

The Method of Powders.—The *second* method of obtaining diffraction effects from crystals (the method of powders), is in a sense a generalization of the one just discussed. If a parallel beam of monochromatic X-rays is caused to fall upon a fine crystalline powder put in place of the crystal at *C* of Fig. 10 (page 204), a number of images of the slit produced by different planes of atoms of the crystal will be obtained upon the photographic plate at *D*. For instance, if the powder is that of a cubic crystal, some of the particles of this powder will have the orientation necessary for reflection from, let us say, the cube face, others for reflection from the octahedral face, still others from the dodecahedral face, and so on: consequently, images from each of these planes will appear upon the film. The kind of photograph that is obtained in this way is shown in Figs. 16 to 19.[19]

The information supplied by a powder photograph is about the same as that obtained by spectrometer measurements, except that now a single experiment furnishes a large number of reflections which in the other case would have to be made upon each face separately. This is obviously a great advantage. The pro-

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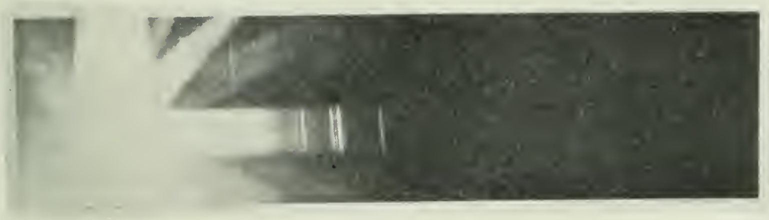
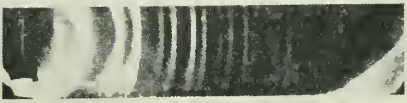
[19] Figs. 16 and 17 are given by A. W. Hull, *Op. cit.;* Figs. 18 and 19 by H. Bohlin, *Ann. d. Phys.,* 51, 421, 1920.

FIG. 15.



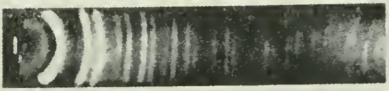
The X-ray spectrum of tungsten using sodium chloride (cube face) as a grating.

FIG. 16.



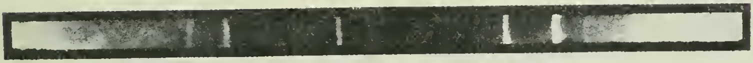
The powder spectrogram from powdered silicon.

FIG. 17.



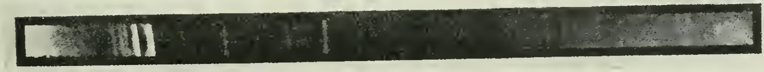
The powder spectrogram from diamond.

FIG. 18.



The powder spectrogram from nickel.

FIG. 19.



The powder spectrogram from magnesium.

cedure at the same time has several serious disadvantages, however: (1) it is greatly to be doubted if the photometered intensities of reflection, such as are to be obtained from these photographs, are at the present time as accurate as are the results derived from the use of the ionization chamber; (2) the amount of material which is reflecting X-rays in the formation of any one of these images is extremely small, so that relatively very long exposures are required; (3) partly because of this small amount of diffracted energy, the images are of considerable width, so that planes having about the same relative spacings—which are at present the most useful in studying the structure of crystals—will give effects which overlap one another; (4) used by itself this method fails to identify the reflection of any plane with a particular image. While this last objection is not serious when we are dealing with very simple compounds, it is exceedingly important for all of the more complicated cases.

The great use of this method lies in its opening up for study a vast number of chemical compounds which do not crystallize well. At present it is not known whether the atoms of many kinds of substances are arranged in an orderly fashion or not. For instance, are the individual particles of a colloidal substance in reality extraordinarily minute crystals, or are they more properly to be looked upon as more or less haphazard agglomerations of atoms? Or, are many of the naturally occurring minerals, such as chalcedony or the opal, perfectly disordered groupings of atoms, or are they built up of the minutest crystals which stand in disordered relations to one another? This method of obtaining diffraction effects may be expected to answer such questions as these. This field is, however, thus far practically unexplored.[17] Further, are liquid crystals crystalline in the sense that they are made up of a regular arrangement of atoms in space? We have here a method of attack for deciding it. If the atoms within the *molecules* of complicated organic compounds stand in a definite orientation to one another, then such compounds should give diffraction effects *even in the liquid state*. Debye and Scherrer [18] believe that they have obtained diffractions from *liquid benzine* which prove the existence of the benzine ring; in fact, it is said to be 6.02×10^{-8} cm. on an edge and 1.19×10^{-8} cm. thick. This same method finds its use even in the field of chemical analysis.[19] Suppose that we have a substance which on solution gives a test for, let us say, sodium and potassium, chlorine and iodine. Is it a mixture of sodium chloride and potassium iodide, or is it a mixture of sodium iodide and potassium chloride, or are all four present together? The method we have been discussing will decide it, for each of the substances is characterized by its own distance between atoms, and once the pattern of images which each of these substances furnishes is known, it is only necessary to search for these same patterns in the photograph obtained from the mixture to be analyzed.

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[17] See, however, S. Kyropoulos: *Zeit. anorg. Chem.*, 99, 197, 1917.

[18] P. Debye u. P. Scherrer: *Nach. Kgl. Ges. Göttingen*, December 17, 1915.

The Method of Laue Photographs.—The *third* method of obtaining diffraction effects from crystals is the original method of Laue. In this instance X-rays are passed through thin sections of individual crystals in a direction normal or nearly normal to some important crystal face. In this way reflections from a relatively enormous number of different crystal planes are obtained at one time. Some Laue photographs have been prepared which show nearly a thousand reflections; it is very common that the number should lie around three to four hundred. Of course several of these spots may belong to the same crystal form, but in spite of this fact the number of different kinds of planes that give reflections in a single photograph is very large.

In contrast with the method of powders the principal use of the *transmission method* lies in its application to the determination of the structures of crystals. A study of the Laue photographs from a crystal, when combined with a spectrometer determination of the number of molecules associated with the unit of structure, supplies more data for distinguishing between the various possible arrangements of its atoms than does any other single method. Transmission photographs are of particular use at the present time because the relatively large amount of data which they furnish makes it possible to dispense to a large extent with the assumptions concerning the reflecting powers of the atoms and the effect of spacing upon the intensity of reflection. As already pointed out, unless some entirely new procedure is devised, it is only by taking advantage of the relatively few and scattering instances where structures can be investigated without the help of both of these two "laws" that direct progress can be made. It remains to be seen whether the Laue photographs will continue to give the most usable information after the forms of these two "laws" have been determined.

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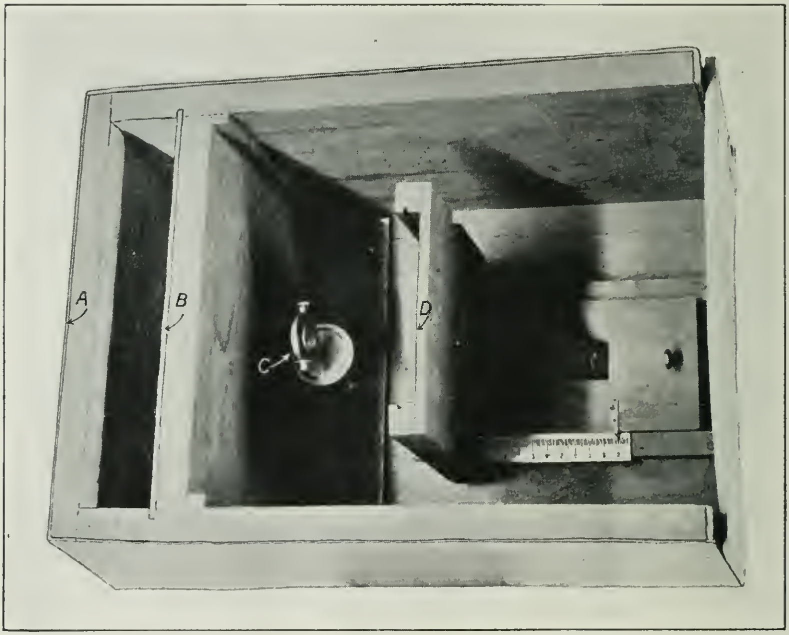
[19] A. W. Hull: *J. Am. Chem. Soc.*, 41, 1168, 1919.

Whereas the other two methods employ X-rays of a single wave-length, the Laue photographs are obtained by the diffraction of that part of the radiation from an X-ray tube which, by reason of its analogy to white light, is called the "white radiation." Fig. 15 shows the spectrum of tungsten. Spectrometer measurements make use of the line radiation, the characteristic radiation; the Laue photographs are produced by the continuous portion of much shorter wave-lengths. This is alike an advantage and a disadvantage: a disadvantage because we must devise methods of studying the Laue photographs which will permit the determination of the wave-length; an advantage (1) because the wide range of wave-lengths that are available permit reflections from

FIG. 20.



A form of the apparatus required for the preparation of Laue photographs. *A* and *B* are pinhole lead slits; the crystal holder *C* permits setting the section of the crystal at any desired orientation; *D* is a movable plate holder. Other and more complicated forms have been used; this one is desirable chiefly because of its simplicity.

a large number of planes for a definite setting of the crystal, and (2) because the shortness of the wave-lengths makes it possible for planes with very small spacings—and complicated indices—to give reflections that can be readily studied.

Fig. 9 (page 202) shows the Laue photograph that is obtained by passing X-rays through a thin section of magnesium oxide cut, or cleaved, parallel to the cube, (100), face.[20] In Fig. 1 (page 200) the pinhole beam of X-rays strikes this thin section of the crystal mounted at *C*; most of it passes directly through the crystal and forms an undiffracted image of the pinholes at *O*; the rest of the rays are "reflected" by the various planes of atoms in the crystal and produce a group of images, each one corresponding to a crystal plane, arranged about this central spot (Fig. 20).

The relative positions of the reflections from the different planes are conditioned only by the kind of symmetry which the crystal exhibits; the absolute positions of these spots upon the plate depend on the distance from the crystal section to the photographic plate. The patterns from different cubic crystals, or from two other crystals which have the same axial ratios and belong to the same system of crystal symmetry, differ from each other then simply in the relative intensities of the reflections from the various planes; this of course depends upon the arrangement of the atoms within the crystal and upon their relative "reflecting" powers. Consider the reflection from the plane containing the line CP and parallel to the Y axis of a cubic crystal (Fig. 21). The intercepts of this plane upon the Z and X axes are in the proportion of 1 : 2; the Y intercept is infinity. Since the ratio of the intercepts of the plane are thus $2 : \infty : 1$, its indices must by definition be 102 ($\frac{1}{2}$, 0, 1). If the angle between this plane and the incident rays is θ, the reflection will be along CR, where the angle $RCO = 2\theta$. In a similar fashion the position of the reflection from any plane can be determined from the characteristics of symmetry of the diffracting crystal. Conversely, it is possible to get such characteristics as the axial ratio of a crystal from a study of the Laue photographs.

This purely geometrical problem of identifying the reflections that are obtained upon the photographic plate with those planes that may be thought of as producing them, can be easily solved with the aid of methods of projection familiar to the crystallographer. Likewise the distance between like planes in terms of the indices of these planes for each of the units of structure which underlie crystals can be obtained from geometrical considerations alone. Furthermore the distance from the crystal to the photographic plate and the distance of a reflection from the central spot give the angle of its reflection. Then with the aid of expression (1) it is possible to get a value for $n\lambda$, the product of the order of the reflection into the wave-length of the reflected X-rays, after one of the absolute dimensions in the crystal has been obtained from an X-ray spectrum measurement. By tilting the crystal so that the X-rays do not pass through it along some important axis, different planes of the same form are inclined at different angles to the incident beam and consequently must reflect X-rays of different wave-lengths. By plotting the intensity of the reflection from planes belonging to the same form against the wave-lengths of the X-rays they are reflecting, points of a curve will be obtained which represents the effect of the X-rays upon the plate. The curves thus arising, one for each different kind of reflecting plane, can be compared in the same wave-length. The data so obtained[21] are serviceable in distinguishing be-

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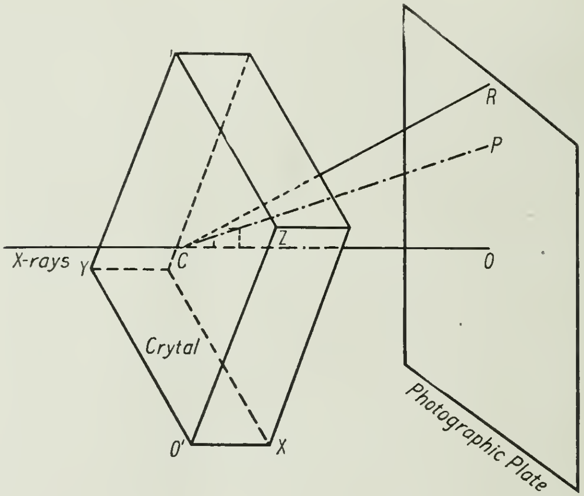
[20] Ralph W. G. Wyckoff: *Am. J. Sci.*, 1, 138.

FIG. 21.



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[21] S. Nishikawa: *Op. cit.* Ralph W. G. Wyckoff: *J. Am. Chem. Soc.*, **42**, 1100, 1920; *Phys. Rev.*, **16**, 149, 1920; *Am. J. Sci.*, **50**, 317, 1920.

tween the possible arrangements of atoms for the crystal under investigation.

Résumé.—A brief outline has now been given of the essential features of the three ways, as they exist at the present time, of attacking the problem of the structure of crystals. It may be well to collect the outstanding features of these methods to show how they are related to one another, and to indicate again the present status of the work in this field.

The start toward determining the arrangement of the atoms in crystals was made by looking around in each case for a structure which would explain the relative distances apart of planes of atoms in directions normal to a few crystal faces. Several chemically and crystallographically simple compounds—the alkali halides, zinc blende, the diamond, fluorspar—were thus studied. Assuming then that the structures thus obtained actually represent the arrangement of atoms within these crystals, the wave-length of X-rays was deduced with the aid of expression (1) from a knowledge of the density of the crystals and the number of molecules in the gram molecule. Further, taking this as the proper value for the wave-length of X-rays, we have proceeded to use it to determine the amount of mass to be associated with the unit of structure of every crystal which has subsequently been studied. The objection to this procedure is, as we have already pointed out, that those original structures, upon the correctness of which the value for the wave-length of X-rays has been based, have never themselves been shown to be the *only* structures which are in agreement with the experimental data. The strong indication of correctness given to this value of the wave-length by the fact that it fits in so satisfactorily with the large amount of data that has since accumulated makes this objection now a more or less formal one.

The determinations thus far made of the structure of crystals have been carried out by two distinct methods of procedure—or perhaps it would be better to say from two different points of view. Most of them have followed closely the early determinations in searching around for some grouping of atoms which would account for a certain limited amount of experimental data. The structures thus obtained have been considered to represent the actual arrangement of the atoms within the crystal. In many cases they are the simplest arrangements which could be found and as such have a certain, but very doubtful, degree of probability. Without exception, probably, they are not, however, the only ones which could be fitted into the existing data.

Only a few crystals have as yet been studied, starting from the point of view suggested by the theory of space groups. Following such a method of procedure we would most ideally make use of all three ways of getting diffraction effects—the spectrometer, the method of powders and the transmission (Laue) photographs. The first step would get a reflection spectrum from some important crystal face. This measurement will decide the number of chemical molecules (or usually the numbers, since more than one is possible because of the uncertainty as to the order of the reflection) that can be associated with the unit underlying the crystal. With this as a basis, and using the results of the theory of space groups, *all* of the ways in which the atoms of the compound could possibly be arranged can be written down. It is then a comparatively simple matter to decide exactly what data are required to distinguish between these various possibilities and to get them by whichever of the three methods of obtaining diffraction effects will supply them most readily. Even if it is impossible, with the present limited amount of information about the mechanism of the reflection of X-rays, to eliminate all but one of these groupings, still we always have exact knowledge as to the status of the determination. The element of guessing is thus quite definitely eliminated.

A DISCUSSION OF SOME OF THE STRUCTURES THUS FAR STUDIED.[22]

By making the seemingly plausible assumption that chemically simple compounds have their atoms in some sort of a simple arrangement in space, it is possible, as we have seen, to determine the crystal structures of quite a large number of compounds. It is perhaps worth while to consider to what results the structures obtained with the aid of this assumption will lead. A knowledge of the arrangement of the atoms in a crystal is essential to the adequate treatment of a large field of problems. The crystallographer who is concerned with finding some explanation for cleavage, or for a kind of twinning, will find an acquaintance with the crystal structure indispensable; the manner of the arrangement of the atoms in a compound forms a rational basis upon which to build a discussion of the relative occurrences of crystal faces.[23] Furthermore the physicist who is interested in the structure of the atom must produce a model which will account for the structures of crystals. Yet again the chemist may look to these same structures for information as to the nature of the forces which are binding atoms together, for evidence of the existence or non-existence of the chemical molecule and for some light upon the nature of what we have been accustomed to call the valencies of the atom.[24] Quite recently attempts have been made to build upon these determinations of the structure of crystals a quantitative measure of such physical properties of the solid as its compressibility, as well as to try to explain, upon the basis of a definite model of the atom, some of the simpler struc-

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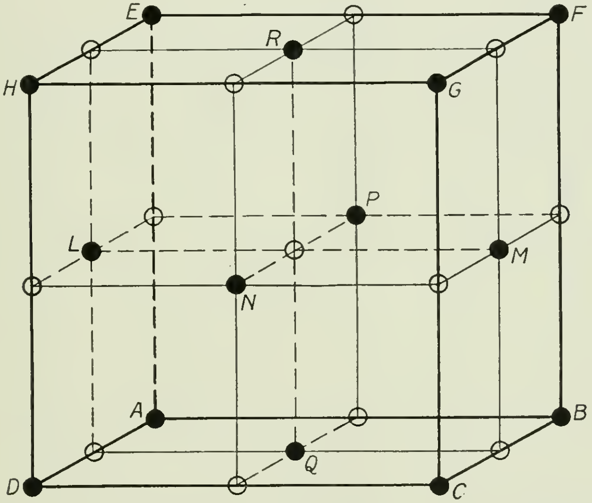
[22] Not all of the crystals that have been studied will be discussed. Some, like fluorspar, CaF_2, cannot as yet be satisfactorily considered; many other determinations seem to be of more or less doubtful value.

FIG. 22.



The sodium chloride arrangement. The black circles represent the positions of the atoms of one kind; the white circles those of the second kind of atoms. The alkali halides and the oxides of the divalent metals seem to have this atomic arrangement. Either the black atoms or the white ones have the grouping of the closest cubic packing of spheres.

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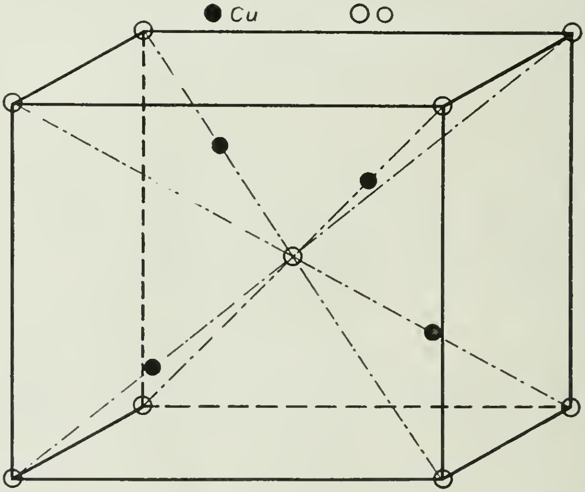
[23] Ralph W. G. Wyckoff: *Am. J. Sci.*, 50, 317, 1920. P. Niggli discusses from this point of view the development of faces by crystals. *Zeit. anorg. Chem.*, 110, 55, 1920.

[24] For instance, see I. Langmuir: *J. Am. Chem. Soc.*, 38, 2221, 1916; Ralph W. G. Wyckoff: *J. Wash. Acad. Sci.*, 9, 565, 1919.

tures.[25] The problems of the chemist, while by no means necessarily the ones whose ultimate solution will be most easily obtained, are nevertheless the ones to which the sort of information furnished by a knowledge of the structure of crystals is most readily applicable. The data as yet at hand are so meagre—and the determinations themselves are, as already emphasized, of sufficient uncertainty—that the conclusions at which we arrive must be only provisional.

Metals.—The structures of a relatively large number of metals have been studied. Most of them appear to have the arrangements that would result from the close packing of bodies spherical or nearly spherical in shape. There are two forms of this close packing of spheres: (1) the closest packing, which has hexagonal symmetry, and (2) the more important cubic face-centred arrangement, which is nearly as close a grouping (Fig. 22). Aluminum,[26] silver, thorium, lead, copper, calcium, indium, pal-

FIG. 23.



The cuprous oxide arrangement. Each monovalent copper atom is surrounded by *two* equally distant oxygen atoms and each divalent oxygen atom by *four* copper atoms. The white atoms alone have the body-centred grouping.

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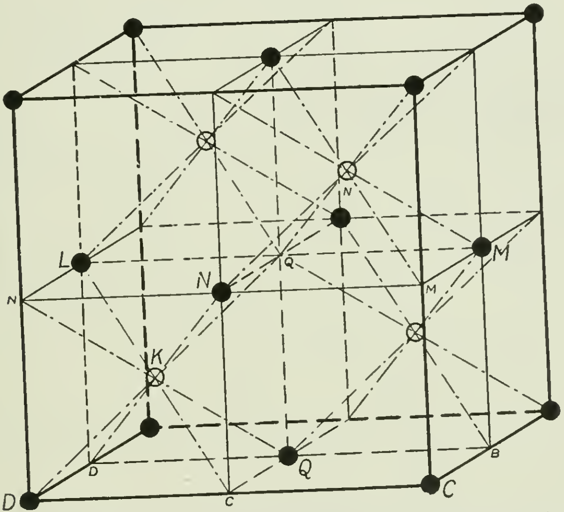
[25] M. Born and A. Landé: *Verh. deut. Phys. Ges.*, 20, 210, 1918; and several other papers by the same authors.

[26] A. W. Hull: *Phys. Rev.*, 10, 661, 1917; *Science*, 52, 227, 1920. P. Scherrer: *Phys. Z.*, 19, 23, 1918. H. Bohlin: *Ann. d. Phys.*, 61, 421, 1920. W. L. Bragg: *Phil. Mag.* (6), 28, 355, 1914. L. Vegard: *Phil. Mag.* (6), 31, 83, 1916.

ladium, and iridium are among the elements which have been shown to have this cubic close-packed grouping. Zinc,[27] cadmium, ruthenium, and magnesium, on the other hand, approach to the hexagonal closest packing. Several elements, however, such as iron,[28] chromium, titanium, sodium, tantalum, and tungsten crystallize in the less dense body-centred grouping (Fig. 23). Nickel[29] appears to be sometimes body-centred and sometimes face-centred. In attempting to deduce from these structures any information concerning either the bonding forces between the atoms or the structures of the atoms themselves, it must be borne in mind that there is always the possibility in a metal of one or more electrons functioning as "silent (so far as X-rays are concerned) partners" in the arrangement. For this reason the metals, though the simplest of compounds, are of all simple compounds perhaps the most dangerous as bases for further deductions.

FIG. 24.



The zinc sulphide arrangement. In this arrangement each white atom is distinct from four black atoms and each black atom from four white ones. If the black atoms are identical with the white ones, the arrangement is that which is found for the diamond.

Compounds of the Type AB.—Several compounds of the type

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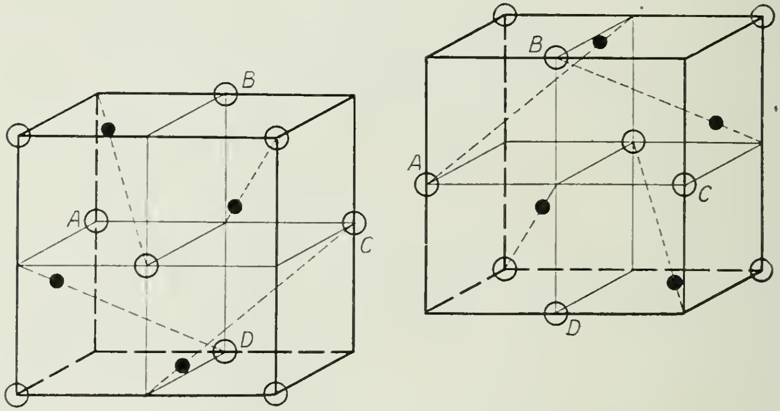
[27] A. W. Hull: *Op. cit.*

[28] A. W. Hull: *Op. cit.* P. Debye: *Phys. Z.*, 18, 483, 1917.

[29] A. W. Hull: *Phys. Rev.*, 10, 661, 1917. H. Bohlin: *Op. cit.*

AB, where *A* is a metal atom and *B* is an electronegative atom, have been studied. All of the alkali halides have the "sodium chloride arrangement" (Fig. 22) wherein each atom has six atoms of the opposite kind equally near to it. The divalent metal oxides, magnesium and calcium, cadmium and nickel oxides,[30] all have this same structure. Galena (lead sulphide) exhibits the same grouping. Zinc blende (zinc sulphide), on the other hand, has a different structure (Fig. 24). In this case each zinc atom is surrounded by four equally distant sulphur atoms, while each sulphur atom has about it four zinc atoms. Zinc oxide exhibits a still different grouping of atoms; but again each zinc atom is surrounded by four oxygen atoms while each oxygen atom has about it four zinc atoms. Cadmium sulphide and wurzite (hexagonal zinc sulphide) have the same atomic arrangement as zinc oxide.[31]

FIG. 25.



The pyrites arrangement. The black sulphur atoms are so spaced along the diagonals of these little cubes that each iron atom has six and each sulphur atom four equally near atoms.

The immediate conclusion to be drawn from these structures is that there is no unique connection between the arrangement of the atoms composing them and their chemical valencies. A qualitative explanation of the structures of these compounds is nevertheless possible. From other evidence it has seemed probable that the atoms in crystals of potassium chloride and related compounds are electrically charged. Upon this basis, then, the alkali halides appear as aggregates of equal numbers of positively and negatively charged atoms. When the atoms are doubly charged, as is presumably the case with magnesium or calcium oxide, for instance, the distance between the atoms is much less than between those of the alkali halides. Calcium carbonate and the divalent carbonates isomorphous with it ($MnCO_3$, $FeCO_3$, etc.) have the same structures if the carbonate groups are substituted for the electronegative atom.[32] The large CO_3 group may be thought of as squeezing out the sides of the cube till it has the form of an obtuse rhombohedron. Similarly cæsium dichloroiodide ($CsICl_2$) has the same arrangement as cæsium chloride if the group of atoms ICl_2 is substituted for chlorine. In this instance the ICl_2 atoms are all strung along the body diagonal so that it may be imagined as distorted from a cube to an acute rhombohedron.[33]

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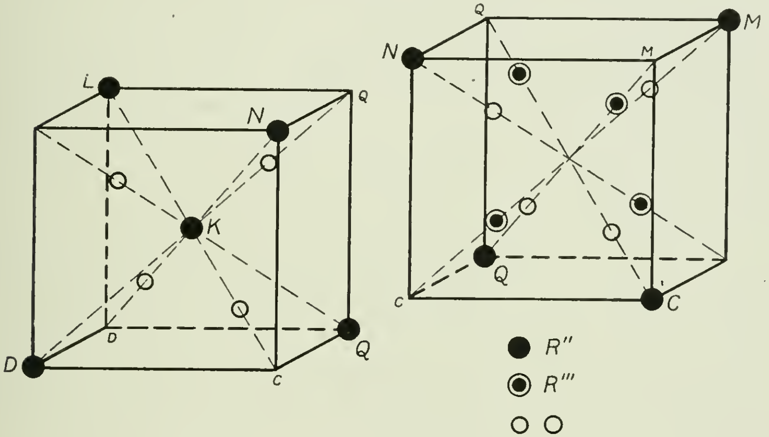
[30] W. P. Davey and E. O. Hoffman: *Phys. Rev.*, 15, 333. 1920.

[31] W. L. Bragg: *Phil. Mag.* (6), 39, 647, 1920.

FIG. 26.



The spinel arrangement. The divalent metal atoms of a spinel occupy *all* of the positions of Fig. 24. The arrangement of the other atoms is here shown for the two typical divisions of this unit. Each divalent metal atom (R'') is equally distant from *four* atoms; each trivalent metal atom (R''') from *six* atoms; and each divalent oxygen atom (O) from *four* atoms.

Other Simple Compounds.—A number of other simple compounds have been studied with a considerable degree of care. If carbon atoms are placed at the positions occupied by both zinc and sulphur atoms in zinc blende, we obtain the arrangement of the atoms in the diamond (Fig. 24).[34] In pyrites each sulphur atom is surrounded by four equally distant atoms and each iron atom by six atoms[35] (Fig. 25). In cuprous oxide each copper atom is equally near to two oxygen atoms, while each oxygen atom has about it four copper atoms.[36] Magnetite, as a typical spinel, has been studied with great care, and in spite of its rather complicated chemical composition its structure is in all probability that given in Fig. 26.[37] In this case each divalent metal is surrounded by four, and each trivalent metal by six, equally distant atoms. In each of these cases it is to be noted that the number of the nearest atoms to any atom is always either equal to its chemical valence or is twice that number. The constant recurrence of this relation suggests that it may be other than purely an affair of chance. Furthermore, a consideration of the sorts of chemical bonding which are conceivable on the basis of our present knowledge of the structure of the atom points to the possible existence of just such a relation as this.

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[32] W. L. Bragg: *Proc. Roy. Soc.*, A **89**, 468, 1914. W. H. Bragg: *Phil. Trans.*, A **215**, 253, 1915. Ralph W. G. Wyckoff: *Am. J. Sci.*, **50**, 317, 1920.

[33] Ralph W. G. Wyckoff: *J. Am. Chem. Soc.*, **42**, 1100, 1920.

Information to be Derived from the Structure of the Atom.[38]—A neutral atom appears to be made up of a minute positively charged nucleus surrounded by enough electrons to neutralize the nuclear charge. The chemical inertness of certain of the elements—the rare gases of the atmosphere—and the fact that atoms having one, two, three, and in some cases four, more electrons than a rare gas, exhibit a marked tendency to lose just enough electrons in becoming positively charged to revert to the configuration of the inert gas, seem to point to the existence of certain especially stable configurations of electrons in atoms. For instance, sodium with one more and magnesium with two more electrons than neon readily lose one and two electrons respectively in becoming positive sodium and magnesium ions. Furthermore, as the electronegative elements are approached, a strong tendency becomes evident to add on enough electrons, beyond the number required for atomic neutrality, to complete the next stable arrangement. If one of the atoms of a compound is highly electropositive and another strongly electronegative, the latter may be able to extract, as a result of this tendency, electrons from the positive atom; the compound in the solid state thus becomes, as we have supposed to be the case with the alkali halides, an aggregate of an equal number of positive and negative " ions." Such a union has been called a *polar bonding.* If, however, the combining atoms are both either strongly electronegative or are to be found among the elements of an amphoteric and less pronounced electrical character, then each atom will strive, without complete success, to abstract electrons from the other in order to complete its especially stable group. The electrons thus held in common by two atoms form a second sort of bonding—the *valency bonding.* Since a complete valence unit (in the old chemical sense) consists both of the tendency of one atom to acquire an electron from another and the tendency of some other atom to take one of this same atom's electrons, the number of electrons in combination with any particular atom may be twice as great as its chemical valence. Such valency bondings must be supposed to be operative between the atoms in those compounds of the sort discussed which are not of the sodium chloride type. This explanation accords well with the natures of such compounds as the diamond and carborundum, and accounts in a satisfactory manner for the unions between the chlorine atoms in chlorine gas or for the bonding between carbon and oxygen in the carbonate group. It is surprising, however, to find some metals, as zinc and copper (in zinc sulphide and cuprite), appear to exhibit the same sort of union in some of their compounds. It should be pointed out that the only metals for which this rule fits, iron, zinc, and the like, are without exception atoms in the centre of a long period of the periodic table. About the arrangement of the outside electrons of these atoms nothing is known at present. Of course it may be argued that we are dealing with only chance agreements with a rule, but it must be remembered that such structures as zinc sulphide depart so far from being closely packed arrangements of atoms that some sort of directional character to the forces of combination between their atoms seems necessary in order to account for their existence as stable groupings.

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[34] W. L. Bragg: *Proc. Roy. Soc.*, A **89**, 277, 1913. W. H. and W. L. Bragg: *Ibid.*, 468.

[35] W. L. Bragg: *Op. cit.* P. P. Ewald u. W. Friedrich: *Ann. d. Phys.*, **44**, 1183 (1914).

[36] W. H. and W. L. Bragg: "X-rays and Crystal Structure," p. 155.

[37] S. Nishikawa: *Op. cit.* W. H. Bragg: *Phil. Mag.* (6), **30**, 305, 1915.

[38] J. J. Thomson: *Phil. Mag.* (6), **27**, 757, 1914. G. N. Lewis: *J. Am. Chem. Soc.*, **38**, 762, 1916. Ralph W. G. Wyckoff: *J. Wash. Acad. Sci.*, **9**, 565, 1919.

In spite of the obvious uncertainties that pervade all these discussions, there seems to be considerable evidence, from a consideration of the crystal structures of such compounds as have been more or less carefully studied, for the existence of two distinct types of solid compounds: (1) *polar compounds,* wherein the bonding between the atoms, or at least between certain groups of atoms, is polar; and (2) *valency compounds,* the atoms of which are bound to other atoms by holding electrons in common. A consideration of organic compounds, none of which have thus far been successfully studied using the X-rays, forces us to a third kind of compound; (3) the *molecule-forming compounds,* built of groups of atoms (the chemical molecules) held together presumably by relatively weak stray fields of force. It will be noticed that in solids of the first two types no molecules in the chemical sense of the word exist: each crystal or piece is a single chemical individual.

DECEMBER, 1920.

A Qualitative Reaction for Magnesium.—F. EISENLOHR (*Ber.*, 1920, vol. liii, 1476) describes the following test for magnesium. An alcoholic solution of alkanet root is prepared and to 5 c.c. of it is added a drop of ammonium carbonate solution of 2N strength. This produces no appreciable change of color, but if additions are made of a few drops of neutral solutions of either magnesium, barium, calcium, strontium or manganous salts the following effects are respectively produced:

Magnesium	Barium	Calcium	Strontium	Manganese (ous)
blue violet	no change	blue	blue violet	blue violet

The colorations produced by magnesium, strontium, and manganous salts are not strikingly different, but if the solution is acidified with not more than two drops of 2N hydrochloric acid, the liquid changes to bright red, and then, if again rendered alkaline by a like volume of ammonium carbonate solution, becomes, in the presence of magnesium, blue violet. In dealing with an ordinary phosphate precipitate, this is dissolved in 2N hydrochloric acid, and a portion of the alkanet solution is mixed with a drop of the acid solution, and then one to two drops of the ammonium carbonate solution, when the presence of a magnesium compound will be shown by the production of the blue violet. If magnesium is not present, the original color of the alkanet solution will appear.

The alkanet solution must not be diluted with water, as this will give rise to a hydrolysis of the ammonium carbonate by which ammonium hydroxide will be produced.

H. L.

FLASHING SPEEDS OF INCANDESCENT SIGNAL LAMPS.*

BY

A. G. WORTHING.

Nela Research Laboratories.

SYNOPSIS.

This paper represents a portion of a study of the theory of signalling units involving incandescent lamps, which was undertaken in response to a request from the National Research Council and the U. S. Signal Corps for the development of a unit for use in daylight signalling.

Filament Characteristics Involved.—Various factors involving signalling speed, where the telegraphic dot-and-dash signals are produced by the flashing of an incandescent lamp, are discussed broadly in a contrast of tungsten with carbon for filament material. The most important factors are: (1) the change in resistance with change in temperature; (2) the quantity of energy required to heat the filament through a given temperature range; (3) the total emissive power of the filament material; (4) the maximum temperature of a flash, and (5) the efficiency of the radiation in producing vision. For lamps of equal voltage, life and luminous flux, a tungsten filament responds more rapidly than carbon during the heating portion of a flash by a factor of six or seven; during the cooling portion of a flash by a factor of 2.5.

Observed Speeds and Their Comparison with Computed Values.—A photometric method of studying the performance of lamps on flashing is described and results obtained with various lamps are presented. These are compared with computed values based on steady current measurements and the supposition that a lamp filament on heating or cooling passes through a succession of steady states. The agreement is quite satisfactory, excepting the case of a filament immersed in hydrogen, where the discrepancy may be ascribed to ionization effects.

Speed Function.—A simple function Q (equation 12), involving only steady current measurements of wattage, resistance

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* Communicated by the Author.

and temperature in the neighborhood of the maximum temperature of a flash, together with a knowledge of the thermal capacity of the filament, will serve quite accurately in rating lamps as to their flashing speeds.

Some Fundamental Generalizations.—(1) The time required for a filament to heat to approximately its maximum brightness exceeds greatly the time required in cooling to effectively zero brightness.

(2) The higher the maximum temperature of a flash, the greater is the speed of the flash.

(3) The smaller the filament, the greater is the speed of the flash.

(4) The less the resistance in a circuit external to a flashing tungsten lamp, the greater is the speed of the flash.

(5) The speed of flashing for a given filament at a given temperature in various atmospheres—including in vacuo—is greater, the greater the gas loss.

(6) For lamps of the same open filament construction, the same luminous flux, and the same average life at a fixed voltage, the speed of flashing is greater, the greater the gas loss.

Ribbon Filaments Versus Wire Filaments.—The quantity of material in a ribbon filament is less than that in an equivalent wire filament. Therefore, in gas-filled lamps, by going from a wire filament to a ribbon filament we may obtain either a considerable increase in signalling speed, or, often without a reduction in speed, a higher efficiency by choosing an atmosphere involving a decreased gas loss. For example, a lamp containing a ribbon filament in argon, proposed in response to the above request, when compared with a lamp containing a wire filament in nitrogen which was its nearest competitor, indicated speeds and efficiencies in favor of the ribbon filament lamp of about 1.6 and 1.25.

IMPORTANCE OF VARIOUS FACTORS AS INDICATED IN A CONTRAST OF TUNGSTEN AND CARBON FILAMENT LAMPS.

It is a matter of common observation that an ordinary tungsten lamp lights up more quickly than does an equivalent carbon-filament lamp. The contrast, most evident when the older types of carbon lamps are considered, is still quite appreciable for the later Gem lamps containing the metallized graphite filament. This difference in response between tungsten and carbon filaments may be readily analyzed to show the various factors which determine the flashing speeds of signal lamps.

The fundamental law descriptive of the behavior of all incandescent lamps which is applicable here, states that the rate of supply of energy as heat to a filament is equal to the rate of dissipation of energy by the filament plus the rate of storage of energy in the filament. The dissipation of energy may take place through radiation, through ordinary heat conduction to filament supports or through gaseous conduction and convection. In vacuum lamps, of course, no gas losses are present. This law is expressed in equation form as

$$VI = f(T) + cm\frac{dT}{dt} \tag{1}$$

where V represents potential drop, I current, $f(T)$ rate of dissipation of energy at a temperature T, c specific heat, m filament mass, and $\frac{dT}{dt}$ rate of increase or decrease of temperature. The three terms of the equation correspond respectively to the three rates enumerated in the underlying fundamental law. For brevity of reference these will often be referred to as supply rate, dissipation rate and storage rate. During the first part of a flash the storing up of energy in the filament is by far the predominating method by which the supply is disposed of. With increasing temperature the dissipation method becomes more and more effective until, at the maximum temperature, the dissipation rate equals the supply rate and the storage process ceases.

Evidently those factors which affect the flashing speeds of signal lamps do so through affecting the supply rate, the dissipation rate, the amount of energy to be stored up, and, since flashes are measured from a brightness instead of a temperature standpoint, the percentage change in brightness accompanying a given percentage change in temperature.

In contrasting the flashing properties of different filaments, there appear certain factors more or less independent: (1) the change in filament resistance with change in temperature; (2) the quantity of energy required to heat the filament through a given temperature range; (3) the total emissive power of the filament material; (4) the maximum temperature of the flash, and (5) the efficiency of the radiation from the filament in producing vision. It is interesting and worth while to consider how and to what extent these factors are of importance individually. With this in mind, let us contrast the heating up portions of the flashes (omitting for the present that portion of the flash during which cooling occurs) of equivalent vacuum tungsten and Gem lamps in circuits, encountered in signalling practice, containing constant voltage sources with no appreciable resistance external to the lamp.

Factor (1) relating to changes in filament resistance with changes in temperature concerns the supply rate. In tungsten an exceptionally large increase in resistance—of the order of thirteenfold—occurs in heating from room temperatures to ordinary incandescent temperatures; in the Gem lamp the resistance change is practically nil. In the constant voltage circuit met with in signalling practice, a tungsten filament, in consequence of its low initial resistance, experiences a proportionally large initial current, and a correspondingly large initial supply rate. The initial storage rate is equally great. With the gradual increase in temperature and resistance, a gradual diminution occurs in the supply rate until the maximum temperature is reached. The supply rate for the Gem filament in a like circuit is practically constant. Comparing now tungsten and Gem lamps of the same voltage and the same wattage, in which therefore the final supply rates are equal, cause is seen for a great advantage in flashing speed through the use of tungsten. Computations according to a method detailed later, indicate that a tungsten filament operated in a circuit with a constant supply rate reaches 90 per cent. of its maximum brightness in an interval about 1.6 times that required when operated in the constant voltage circuit of normal signalling. Most of the actual difference in time is represented by a delay in heating through the lower range of temperature. The advantage of a tungsten filament over a Gem filament in the heating portion of a flash resulting from changes in resistance may thus be set down as about 1.6.

Factor (2), relating to the thermal capacity of the lamp filament, concerns the storage of heat in the filament. Various measurements on Gem and tungsten lamp show, for the same voltage, wattage and operating temperature, that the heat stored up in the Gem filament is about 1.3 times that stored up in the tungsten filament. The advantage of a tungsten filament over a

Gem filament resulting from differences in the thermal capacity of the filaments is thus of the order of 1.3.

Factor (3) relating to total emissive powers concerns the dissipation rate. The total emissive power of tungsten—the measure of its rate of radiating energy compared with a black body at the same temperature—is generally low, though increasing rather rapidly with increasing temperatures. The total emissive power of a Gem filament is comparatively high and does not change rapidly with changing temperatures. The radiation rates for the lamps being compared represent practically the dissipation rates as defined, and, at their maximum temperatures, are therefore approximately equal to their supply rates. But, on the passage of the filaments through the lower temperature ranges, due to the relatively smaller emissive power (expressed in terms of the value at the maximum temperature) of tungsten, there is relatively a reduced rate of radiation of energy by that metal and thereby a comparatively increased storage rate. Though the advantage is definitely in favor of tungsten, the effectiveness of this factor is small, and for our comparison, may be considered negligible.

Factor (4), relating to the maximum temperature of operation, concerns the supply rate, the dissipation rate and the quantity of heat stored up. Comparing two tungsten lamps of the same voltage and wattage, but with operating temperatures of 2200° K,[1] approximately that of the Gem lamp, and 2400° K approximately that of the low wattage vacuum tungsten lamp, we find that the change in the dimension of the filament in going from the lamp with the lower operating temperature to that with the higher operating temperature is considerable, and that the increase in the quantity of heat stored up resulting from the increased temperature range is much more than offset by the less amount of material heated. The net advantage resulting from the higher temperature is about 1.6. The effect on the supply rate results from the increased change in resistance, an effect already accounted for. The effect on the dissipation rate concerns changes in total emissive power, an effect also already accounted for. The advantage of a tungsten filament over a Gem filament in the heating portion of a flash, resulting from the higher operating temperature of the former, is thus about 1.6.

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[1] Temperatures in the thermodynamic centigrade scale are commonly measured in degrees K. (Kelvin), the zero of which scale is the absolute zero of temperature. °K. = °C. + 273°.

Factor (5), relating to the luminous efficiency of radiation, is the most important factor in the contrast of speeds. It concerns the supply rate and the amount of heat that is stored up. In the preceding paragraphs, equality of voltage and of wattage has been the basis on which lamps have been rated as equivalent. A more just basis, since the eye is the instrument by which flashing signals are tested, is one of equality of voltage and of luminous output. It is in this transition that luminous efficiency considerations enter. Contrasting an efficiency of 4.1 lumens per watt for the Gem lamp with 9.2 lumens per watt for the tungsten lamp at 2400° K, shows that for equivalent lamps from the visual standpoint, the wattage of the tungsten lamp should be only about 45 per cent. of the wattage of the Gem lamp. Considering now two lamps of the same filament material, differing in wattage in this same ratio, it follows that the smaller filament is only 77 per cent. as long, 59 per cent. as great in diameter and 27 per cent. as great in mass as the larger filament. The combined effect of the decreased filament mass and decreased supply rate leads to a flashing speed in favor of the smaller filament equal to about 1.7. Evidently this reasoning may be applied to the case where filament materials are contrasted. The advantage of a tungsten filament over a Gem filament in the heating portion of a flash resulting from differences in the luminous efficiencies of their radiations is thus of the order of 1.7.

Combining the several advantages possessed by tungsten, one would expect that a tungsten lamp flashed in a constant voltage circuit to its normal operating temperature, would reach 90 per cent. of its maximum brightness in somewhat more than one-sixth of the time required by an equivalent Gem lamp flashed to its normal operating temperature. At the time this comparison was conceived the apparatus described later had been dismantled, so that no direct experimental verification of the preceding considerations is offered. However, computations according to the method indicated later point to the real contrast in speeds of the two lamps as being about 1 : 6.5. This is a very satisfactory agreement indicating the correctness of the analysis.

The cooling portion of a flash might be analyzed similarly. However, such a comparison is relatively of much less importance in contrasting filaments for flashing speeds, because the time required for a filament to cool to a negligible fraction, say 5 per cent., of its maximum brightness, is always small in comparison with the time required to heat to 95 per cent. of the maximum brightness. Briefly stated, such an analysis summarized shows that a tungsten lamp during the cooling portion of a flash will respond about 2.5 times as rapidly as the equivalent Gem lamp. The superiority of a tungsten over a Gem filament in incandescent signal lamps is decisive.

In this work, started in response to a request for the development of a unit for use in daylight signalling, emphasis is laid upon variations in tungsten-filament lamps, since simple considerations like those stated above showed them to be much more desirable than any known lamps containing filaments of different material.

EXPERIMENTAL METHOD.

The experimental study of flashing speeds was based upon a method used previously.[2] It consisted in making instantaneous candlepower measurements of a flashing lamp at various instants following the beginning or ending of a current flash.

The arrangement of apparatus used is diagrammed in Fig. 1. L_1 represents the lamp being flashed, L_2 a comparison lamp operated under steady current conditions, P an ordinary photometer head for instantaneous candlepower comparisons of L_1 with L_2. The flashing of L_1 was brought about by the periodic making and breaking of the current through it by means of the electromagnetically operated switch S. Regularity of action and the precise value of the period depended upon the synchronous motor which operated two sliding contacts C_1 and C_2 in the same circuit with the electromagnet of the switch. Positiveness in the action of the switch was secured by means of a spring as shown, which tended to keep it open. Ordinarily the adjustments were such that the circuit containing L_1 was closed only during a quarter turn of the drum D_1. Drum D_2 mounted on the same shaft as D_1 carried an adjustable point contact C_4, which closed once each rotation of the drum, the circuit containing the relay R for a very brief interval only. The operation of R in turn jerked aside momentarily a small opaque screen at the opening of the photometer eyepiece O. For any particular setting of the point contact on D_2, there was a definite phase relation between the exposure of the opening at O and the flash of the lamp L_1. This condition permitted the observer, in arriving at candlepower comparisons between L_1 and L_2, to use any desired number of successive glimpses of the photometric field.

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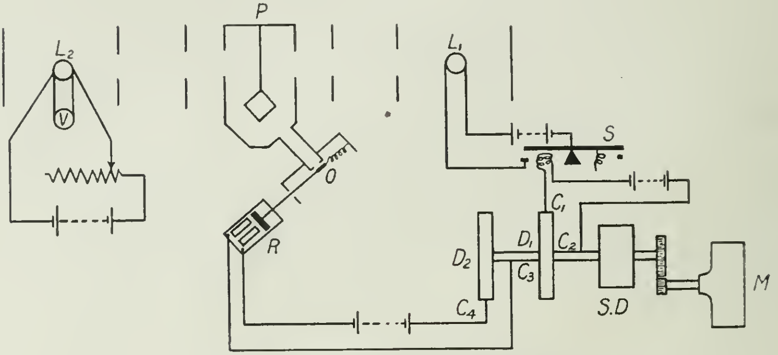
[2] *Lighting Journal*, Nov. 1915; *Phys. Rev.*, 12 p. 199, 1918.

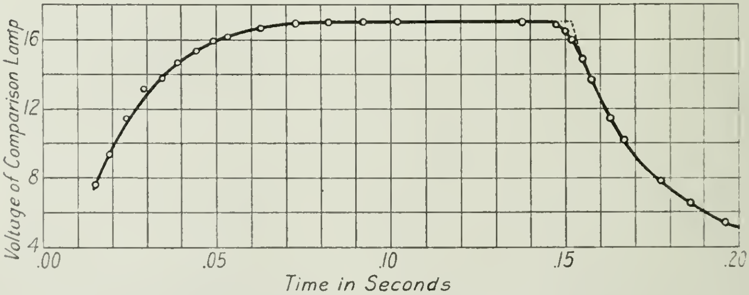
Fig. 1.



Apparatus for testing speed of signal lamps.

The method of procedure consisted in judging for some definite setting of the contact C_4, the momentary deviations from equality in the photometric match, adjusting the current through lamp L_2 for equality, and noting the voltage of lamp L_2. Then the operator adjusted the contact C_4 to a new position and proceeded as before. From a number of such readings, a curve may be platted, showing the voltage of the comparison lamp L_2 as a function of the time elapsing since the beginning of the flash in the

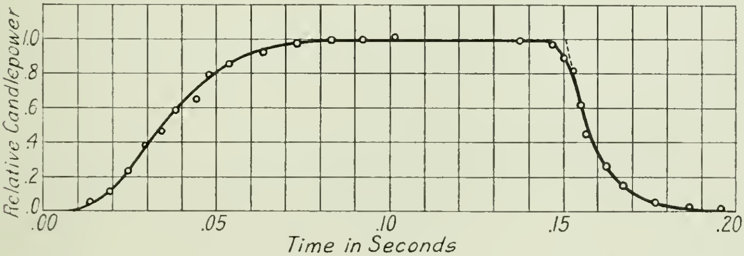
Fig. 2.



The voltage of a comparison lamp required to match in candlepower a 6-volt, 2-ampere, argon-filled, ribbon-filament signal lamp on flashing, as a function of time.

lamp L_1. Such data for a special argon-filled, ribbon-filament lamp[3] are platted in Fig. 2. The consistency of the observations is well shown. Given further the relation between voltage and candlepower for lamp L_2 there follows at once, as shown in Fig. 3, the candlepower variations of the special lamp during a flash. In this case the lamp practically reached its maximum steady candlepower in somewhat less than a tenth of a second. On cooling off the luminous output fell to a few per cent. of its maximum value in considerably less than a twentieth of a second. The consistency obtainable in measurements of this character is shown in Table I, in which certain speed characteristics are given for various lamps proposed for signal purposes.

FIG. 3.



The candlepower as a function of time for a 6-volt, 2-ampere, argon-filled, ribbon-filament signal lamp, on flashing.

It is evident that the observed curves, in case strictly instantaneous glimpses could have been obtained, would have followed much the paths indicated by the dotted lines in Figs. 2 and 3; but, due to the aperture at O being open for an appreciable interval, the cooling effect became manifest previous to the coincidence in time of the interruption of the flashing current and the centre of the time interval during which the opening at O was uncovered. This is quite analogous to the effects due to finite slit-widths in spectrophotometry. The difference in time given by the intercepts of the full and dotted curves on the steady maximum candlepower line represents one-half of the interval of exposure of the photometric field. The total exposure in this instance, as well as

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[3] This lamp was a preliminary lamp of the type recommended by the Nela Research Laboratory for use in a 6-volt, 2-amp. signalling unit for the U. S. Signal Corps. The possibility of manufacturing ribbon filament lamps has depended upon the production of satisfactory ribbon filaments, an accomplishment brought about by Dr. C. F. Lorenz, formerly of this laboratory.

TABLE I.

Data on Ribbon and Wire Filament Signal Lamps Showing Consistency in Speed Measurements.

Lamp	Description	V in Volts	I in Amperes	r/R_m	T	Heating *		Cooling*
						$t_{.2}-t_0$	$t_{.7}-t_{.2}$	$t_{.2}-t_{.7}$
26L	Very open double spiral 0.025 mm. ribbon filament in argon at 600 mm. pressure	7.05	2.15	0.12	3020°K	....	0.019 sec. .020 .015 .019 .019 .017 .020	0.016 sec. .013 .019
80S	Very open double spiral 0.083 mm. wire filament in nitrogen at 600 mm. pressure	5.80	1.91	.04	2980	0.036 sec. .037 .036 .039	.030 .028 .026 .027 .031 .031	.014 .015
S-133-Ar	Moderately open single spiral 0.027 mm. ribbon filament in argon at 600 mm. pressure	6.60	1.84	.16	3020	....	.029 .026 .030 .028 .030	.017

* t_0, $t_{.2}$, and $t_{.7}$ respectively refer to the time at which the flash began, the time at which the filament possessed 0.2 of its maximum brightness, and the time at which it possessed 0.7 of its maximum brightness.

for a large part of the work reported here, was approximately 0.010 second. It is possible to correct these curves and to obtain others showing the results of truly instantaneous glimpses, but generally the accuracy of the observations does not justify this, and such corrections have therefore not been made.

EXPECTATIONS BASED ON STEADY CURRENT MEASUREMENTS.

Before discussing the experimental data, let us consider the flashing speeds which steady current measurements lead us to expect. We shall assume that there is no lag or lead of radiation with respect to resistance [4] during the rapid changes of temperature incident to the flashing of a filament. For a circuit containing no resistance external to the flashing lamp, equation (1) reduces to

$$\frac{V^2}{R} = W + cm\,\frac{dT}{dt}, \tag{2}$$

in which V represents the steady voltage of the battery; R the resistance of the lamp; W the steady wattage corresponding to R; and the other symbols the quantities as already mentioned. Solving for $\frac{dt}{dT}$, we have

$$\frac{dt}{dT} = \frac{cm}{\frac{V^2}{R} - W}. \tag{3}$$

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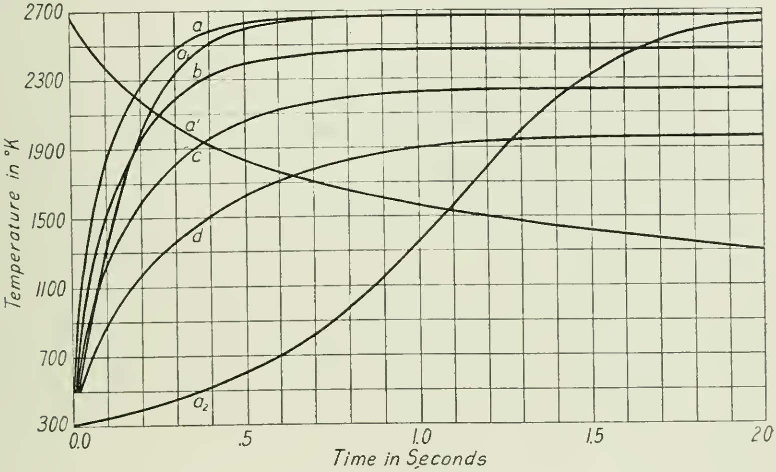
[4] Worthing, *Phys. Rev.*, 12, p. 199, 1918: Gæhr, *Phys. Rev.*, 12, p. 396, 1918.

This equation, together with data showing the relation between resistance, wattage and temperature for a succession of steady states, serve for the computing of the time *dt* required, for any small change in temperature, *dT*. The summation of such small intervals of time over any arbitrarily chosen temperature range gives directly the time required to heat the filament through that temperature range. Similar summations for a number of arbitrarily chosen temperature ranges serve for the platting of a curve showing the temperature of a flashing filament as a function of time.

FIG. 4.



Heating and cooling curves for a 0.258 mm. tungsten filament in vacuo-lamp A-33.

Curve	Condition	r/R_m	T_m
a	Heating	0	2667°K.
b	Heating	0	2478°K.
c	Heating	0	2232°K.
d	Heating	0	1973°K.
a_1	Heating	.17	2667°K.
a_2	Heating	∞	2667°K.
a'	Cooling	—	2667°K.

Making use of the relations between *R*, *W*, *T*, and *c*, found for a certain tungsten vacuum lamp,[5] *A* – 33, flashing curves were computed for various conditions of operation. Fig. 4, curves *a*, *b*, *c*, and *d*, represent four such curves computed for this lamp in constant voltage circuits containing no resistance other than that of the lamp filament. The curves show that the flashing speed for a given filament diameter increases rapidly with increase in the maximum temperature.

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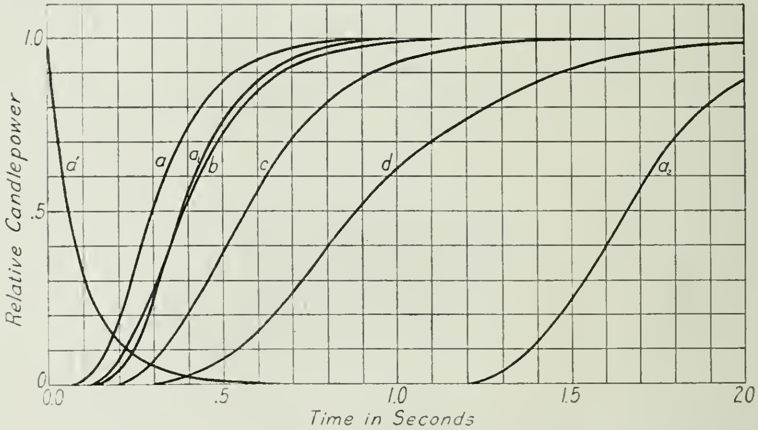
[5] *Loc. cit.*

The term $\frac{V^2}{R}$ of equation (2) is ordinarily zero during the cooling process, and the changes which take place depend only on the state of the filament itself. It follows that whatever the maximum temperature of the flash, the cooling curves for a given filament through a specified temperature range are identical. For example, a filament heated to 2500° K, after cooling to 2000° K, will thereafter cool exactly as though heated initially only to 2000° K.

FIG. 5.



Candlepower time curves corresponding to the temperature time curves of Fig. 4.

When the circuit contains resistance external to the flashing lamp equation (3) reduces to:

$$\left(\frac{V}{R+r}\right)^2 R = W + cm\,\frac{dT}{dt} \tag{4}$$

where r represents the external resistance. A contrast of curves a and a_1, Fig. 4, shows the effect of the introduction of a moderate resistance; a contrast of curves a and a_2 the effect of an extremely large resistance. In this instance, the ordinarily favorable effect of the positive-temperature coefficient of the tungsten filament has become an equally great detriment to rapid flashing.

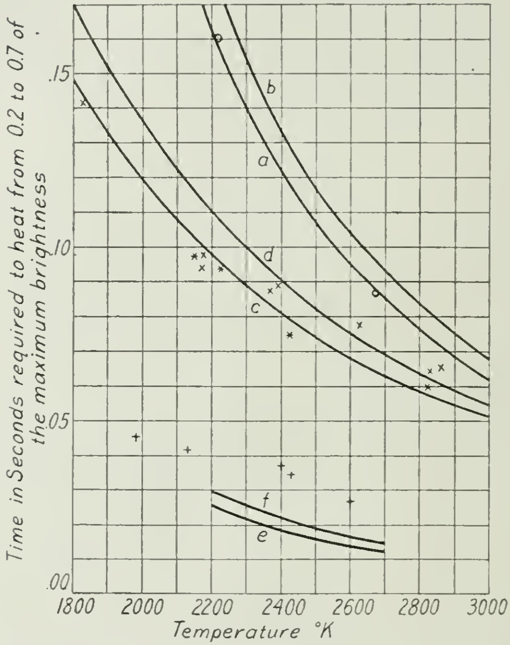
Fig. 5 shows the brightness curves corresponding to the temperature curves given in Fig. 4. The desirability of a high operating temperature and a circuit free from external resistance for rapidity of flashing are perfectly evident. The most evident effect of an external resistance, as has been stated already, is a delay in the appearance of incandescence. It is also to be noted that the time required in cooling down from the maximum brightness to say 5 per cent. of that value is considerably less than that required to heat from room temperature to within the same per cent. of the maximum value, that is to 95 per cent. of the maximum value. This agrees with what has been said already regarding the predominating importance of the heating portion of a flash in determining flashing speeds. This conclusion may seem at variance with common observations on effects noticeable on switching on and off ordinary lamps. The apparent discrepancy is to be ascribed largely to the inertia of the pupillary aperture of the eye and to changes in the retina sensitiveness to light stimuli. On the flashing up of a lamp both factors operate to give the impression of a maximum brightness, or of an overshooting in brightness while the filament is still relatively far from the actual maximum brightness.

Corresponding curves for filaments of the same material, but of different radii, may be obtained from the curves of Fig. 4 and Fig. 5. It may be readily shown, referring to equation (3), that $\frac{V^2}{R}$ and W for a given length of wire both vary as the radius of the filament, while the mass varies as the square of this dimension. This results in corresponding values for $\frac{dt}{dT}$ varying directly as the radii. Therefore, for a filament whose diameter is 0.0258 mm., one-tenth that of the filament considered in Figs. 4 and 5, corresponding curves may be obtained at once from the curves of those figures by dividing the time intervals by ten.

Curves *a* and *b*, Fig. 6, show the computed results for a vacuum lamp having a filament whose diameter is 0.0134 mm. for the condition of no resistance external to the lamp and for a condition of a resistance equal to about one-sixth that of the filament when at 2667° K, the approximate conditions occurring in experimental work with this same size of filament.

The flashing speed for a filament immersed in a gas may be computed on the supposition that the lamp filament on heating up passes through a succession of steady states; that is, on assuming that a filament on passing through 1500° K on its way to a maximum temperature of 2500° K is radiating and losing energy by gaseous conduction and convection at the same rate as it radiates and loses energy in consequence of the gas when operated at a steady temperature of 1500° K. Equations (3) and (4)

FIG. 6.



Times required for lamps with 0.134 mm. tungsten wire filaments to heat from 0.2 to 0.7 of their maximum brightnesses under various conditions, usually corresponding roughly to computed curves *b*, *d* and *f*.

Symbol	Lamp (See Table II)
o	S-150-*V*
x	S-150-*Ar*
*	S-142-*Ar*
+	S-158-*H*

Curve	Atmosphere	r/R2667°K.
a	Vacuum	0.00
b	Vacuum	0.17
c	Argon at 600 mm.	0.00
d	Argon at 600 mm.	0.17
e	Hydrogen at 600 mm.	0.00
f	Hydrogen at 600 mm.	0.17

then become applicable to gas-filled lamps as well as to vacuum lamps. It should be noted here that the quantity W includes the gas loss. Following this plan, curves *c* and *d* of Fig. 6 have been computed for a 0.0134-mm. tungsten filament in argon, and curves *e* and *f* for the same lamp when hydrogen filled. Due to changes in the relative importance of gas conduction with change in filament size, one cannot compute the speeds for one size of filament in terms of those for another size by the simple method shown for vacuum lamps.

EXPERIMENTAL RESULTS.

For comparisons of signalling speeds it is necessary to adopt some criterion of flashing speed. Since all candlepower-time curves seem to have the same shape and to differ mainly in their relative slopes, a measure of their relative slopes would seem a fair criterion. This criterion is not all that could be wished since it does not take account of the time interval required for the filament to reach incandescence. As a measure of this slope and criterion, we have arbitrarily adopted the time required for a filament in heating from two-tenths to seven-tenths of its maximum brightness. This represents referring to Fig. 3, the time of passage through what is sensibly the straight portion of the heating curve. Thereby, also, the errors due to the finite lengths of the glimpses of the photometric field in the experimental work were largely eliminated.

Observed values for such speed criterions are contrasted in Table II and Fig. 6 with the computed values for various lamps. While the agreements are not all that could be desired, they are not bad considering experimental difficulties.

Certain causes for these outstanding differences may be briefly stated. (1) Due to the finite length of glimpses in the photometric measurements, observed values for $t_7 - t_2$ may be expected to be too great, the more so the smaller the value of $t_7 - t_2$. Consideration of apparent lengths of glimpses indicates negligible effects for $S - 142 - Ar$, $S - 150 - Ar$ and $S - 150 - V$; but in the case of $S - 140 - Ar$ and $S - 158 - H$ these effects may amount to 10 per cent. or more. (2) The end coolings of the filaments in $S - 150 - Ar$, $S - 150 - V$ and $S - 158 - H$ were different from those in the lamps used in computation. Their influence becomes more and more prominent with decreasing temperature of flash. Just how this would affect the results is difficult to say. (3) Hydrogen molecules, as shown by Langmuir,[6] dissociate at high temperatures. Above 2000° K or 2100° K, the fractional part of the molecules in a given mass that are thus split becomes quite appreciable. Flashing lamps containing hydrogen, therefore, possess an added method of disposing of energy supplied, which does not occur appreciably in other lamps. A hydrogen lamp as its filament heats up is required to establish and maintain a more and more completely ionized atmosphere. There is in effect an added appreciable method of storage of energy for the filament not considered in equations (2) and (3). This factor is extremely difficult to allow for, but, when taken into consideration, must lead to greater computed values for $t_7 - t_2$, thus lessening the outstanding difference between the observed and the computed values. A contrast of results on $S-140-Ar$ and $S-158-H$ lends credence to this view. (4) The supposition that filaments in gas-filled lamps pass through a succession of steady states is not completely fulfilled. This unquestionably accounted for several

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[6] *Trans. Am. Electrochem. Soc.*, 20, p. 225. 1911; *Phys. Rev.*, 34, p. 401, 1912; *Jour. Am. Chem. Soc.*, 34, p. 860, 1912.

Table II.

Observed and Computed Values of the Rates of Heating and Cooling of Various Tungsten Filaments.

Lamp	Description	$R\frac{r}{m}$	Maximum temperature of flash	Heating *				Cooling *	
				$t_{.2}-t_0$		$t_{.7}-t_{.2}$		$t_{.2}-t_{.7}$	
				Obs. Sec.	Comp. Sec.	Obs. Sec.	Comp. Sec.	Obs. Sec.	Comp. Sec.
S-140-Ar	Straight 0.039 mm. filament in argon at 600 mm.	0.010	2780°K.	0.021	0.014	0.022	0.013	0.009	0.0056
		.011	2490	.026	.018	.022	.016	.007	.0058
		.013	2220	.028	.022	.024	.019	.010	.0058
		.009	2720	.024	.015	.023	.014		
S-142-Ar	Straight 0.134 mm. filament in argon at 600 mm.	.08	2825	.072	.080	.060	.062	.027	.030
		.12	2220	.130	.158	.095	.102	.039	.036
		.28	1855	.216	.....	.103(?)	.162	.036	.039
		.22	2420	.104	.132	.075	.090	.028	.034
		.15	2165	.153	.166	.098	.110	.043	.037
		.16	1980	.183	.193	.110(?)	.134	.035	.038
S-150-Ar	Openly coiled 0.134 mm. filament in argon at 600 mm.	.14	2845	.091	.077	.066	.062		
		.18	2615	.101	.106	.077	.075		
		.19	2380	.133	.137	.088	.090		
		.17	2190	.158	.163	.094	.109		
		.21	2395	.127	.140	.085	.091		
		.24	1860	.234	.247	.141	.159		
		.14	2825	.087	.080	.065	.063		
		(?)	2190	.150	(?)	.098	.109		
S-150-V	Openly coiled 0.134 mm. filament in vacuo.	.14	2680	.097	.091†	.086	.095		
		.17	2220	.141	.154†	.160	.174	.053	.060
S-158-H	Openly coiled 0.134 mm. filament in hydrogen at 600 mm.	.18	2125	.068	.041	.041	.....	.013	.008
		.17	2420	.050	.034	.021	.....	.013	.008
		.14	2600	.035	.028	.017	.....	.012	.007
		.16	2405	.047	.039	.022			
		.20	1975	.059	.042				

* t_0, $t_{.2}$ and $t_{.7}$ respectively refer to the time at which the flash began, the time at which the filament possessed 0.2 of its maximum brightness, and the time at which it possessed 0.7 of its maximum brightness.

† Account has been taken here of the fact that in the vacuum lamp the filament did not cool to sensibly room temperature between flashes.

cases of burn-outs on first flash in some low-voltage signal lamps which were operated at exceptionally high temperatures, though the same lamps had previously withstood for some time the same high temperatures when brought to them gradually.

Summarizing the tests on the flashing speeds, it appears that computed values for the times required to reach two-tenths of the maximum brightness $(t_{.2} - t_0)$ and to go from this condition to seven-tenths of the maximum brightness $(t_{.7} - t_{.2})$ on heating, and then to cool through this same range $(t_{.2} - t_{.7})$ agree well with the observed values in the vacuum and argon-filled lamps containing 0.134-mm. filaments. Considering sources of error, the differences in $S - 140 - Ar$ and $S - 158 - H$ may well be accounted for. If we except hydrogen-filled lamps in which ionization occurs, we probably are not far wrong in assuming that the true values of the speed criterions may be obtained by computation, using the method outlined above. In general we may say in comparing various types of tungsten filament lamps, that the time required for a filament to heat to approximately maximum brightness exceeds greatly the time required in cooling to approximately zero brightness; that the higher the maximum temperature of a flash the greater the flashing speed; that the smaller the filament the greater the flashing speed; that a given filament in hydrogen flashes more rapidly than in argon, and more rapidly in argon than in vacuo.

SPEED FUNCTION FOR RATING LAMPS.

It has already been noted in connection with Fig. 5, that the general form of the candlepower-time curve for a tungsten filament in vacuo, in a constant voltage circuit is not much changed by changing the maximum temperature of the flash or by introducing a small external resistance in the circuit. It might be added that changes in filament size and immersion in gas are likewise of little effect in changing the general aspects. This leads one to suspect that some function might be found which would represent the facts well enough to be taken as a cue to the speed of the lamp. With this in mind consider the rate of change of brightness of a filament with time at or near the maximum temperature during the heating portion of a flash. Equation (4) on rearranging gives

$$(5) \qquad \frac{dT}{dt} = \frac{W_m}{cm}\left[\frac{R/R_m}{\left(\frac{R+r}{R_m+r}\right)^2} - \frac{W}{W_m}\right]$$

Making use of the oft-used expressions

$$(6) \qquad \frac{R}{R_m} = \left(\frac{T}{T_m}\right)^{\alpha}$$

and

$$(7) \qquad \frac{W}{W_m} = \left[\frac{T}{T_m}\right]^{\beta}$$

where α and β are constant for temperatures not far removed from the maximum temperature, T_m, and expanding, we have

$$(8) \qquad \frac{R}{R_m} = \left(1 - \frac{T_m - T}{T_m}\right)^{\alpha} = 1 - \alpha\,\frac{T_m - T}{T_m} + \alpha\,\frac{(\alpha - 1)}{2}\left(\frac{T_m - T}{T_m}\right)^2 - \ldots .$$

and

$$(9) \qquad \frac{W}{W_m} = \left(1 - \frac{T_m - T}{T_m}\right)^{\beta} = 1 - \beta\,\frac{T_m - T}{T_m} + \frac{\beta\,(\beta - 1)}{2}\left(\frac{T_m - T}{T_m}\right)^2 - \ldots .$$

similarly

$$(10) \qquad \left(\frac{R + r}{R_m + r}\right)^2 = \left[1 - \frac{R_m}{R_m + r}\left(1 - \frac{R}{R_m}\right)\right]^2 = \left[1 - \frac{R_m}{R_m + r}\,\alpha\,\frac{T_m - T}{T_m}\left(1 - \frac{\alpha - 1}{2}\,\frac{T_m T}{T_m} + \ldots .\right)\right]^2$$

For temperatures near the maximum, the first two terms of each expansion may be used with but slight errors to replace the infinite series to which they belong. We have then on substituting in (5) for temperatures near T_m

$$(11) \qquad \frac{dT}{dt} = Q\,(T_m - T)$$

where

$$(12) \qquad Q = \frac{W_m\left(\beta + \alpha\,\frac{R_m - r}{R_m + r}\right)}{(CM)_m T_m}$$

Insofar as (11) is exact, Q is a time constant for the flash, indicating that the rate of increase temperature of a flashing filament in a constant voltage circuit is proportional to the temperature difference $(T_m - T)$. A similar expression for the rate of increase in relative brightness of the filament $\frac{1}{B}\,\frac{dB}{dt}$ is obtained when account is taken of the relation between brightness and temperature,

$$(13) \qquad \frac{B}{B_m} = \left(\frac{T}{T_m}\right)^{\theta}$$

in which θ may be considered constant for values of T/T_m nearly equal to unity. There follows

$$\frac{1}{B}\frac{dB}{dt} = \theta\,\frac{1}{T}\frac{dT}{dt} \tag{14}$$

Substitution of $\frac{dT}{dt}$ from (11) in (14) and the elimination of T/T_m by means of an expansion of (13) give

$$\frac{1}{B}\frac{dB}{dt} = Q\,\frac{B_m - B}{B_m} \tag{15}$$

Thus it appears expressing brightness in terms of the maximum, that the rate of increase in brightness in the neighborhood of that maximum is also proportional to Q. Similarity of heating curves suggests, in comparing the speeds of various lamps over any fixed relative brightness range, that while (15) would not hold, the deviations for the different lamps would be found approximately the same, and that the function Q would still serve for comparison purposes; for instance, that

$$Q\,(t_{.7} - t_{.2}) = \text{constant (approx.)} \tag{16}$$

That the function Q, one involving only steady current measurements of wattage, resistance and temperature, in the neighborhood of the maximum temperature of a flash, together with the thermal capacity of the filament, thus involving no candlepower considerations directly, should give the cue to the flashing speed from the light standpoint is on first thought somewhat surprising.

To what extent (16) may be used in representing the results computed on a rigid basis may be seen by referring to Table III. Inspection of the table shows approximate constancy in the product $Q(t_{.7} - t_{.2})$ first with change in the maximum temperature of the flash and second with change in resistance external to the flashing lamp, and third with change in the atmosphere surrounding the filament. Insofar as there is agreement, or lack of agreement, between the experimental and the computed speeds shown in Table II and Fig. 6, there is also agreement or failure on the part of equation (16) in representing actual speed data. Evidently, in a very real sense, the function Q gives the cue to the flashing speed of the lamp and may well be considered the speed function. Different lamps may reasonably be rated as to their flashing speeds through their corresponding Q's.

COMPARISON OF VARIOUS SIGNAL LAMPS FROM DIFFERENT VIEWPOINTS.

The question of flashing speed in considering lamps for signalling purposes is not all important. Usually one is concerned with lamps of a specified voltage, a specified average life—say twenty-five hours—and a specified luminous output.

Table III.

Data Showing with What Approximation Equation (16) Represents Computed Speeds for Various Tungsten Filament Lamps Under Different Conditions of Operations.

Lamp ‡	T	W watts	R ohms	(CM) joules/degree	β	α	$\frac{R-r}{R+r}$	Q $^1/$sec.	$(t_{.7}-t_{.2})$ computed	$Q(t_{.7}-t_{.2})$
A-33	3000°K.	136.5	2.016	0.0216	4.40	1.20	1.00	11.80	0.120 sec.	1.42
	2667	81.1	1.753	.0205	4.52	1.20	1.00	8.49	.167	1.42
	2667	81.1	1.753	.0205	4.52	1.20	.71	7.95	.184	1.44
	2667	81.1	1.753	.0205	4.52	1.20	.00	4.92	.327	1.61
	2232	35.30	1.412	.6190	4.73	1.20	1.00	4.93	.295	1.45
	1800	12.37	1.095	.0175	4.99	1.20	1.00	2.43	.619	1.50
S-142-Ar	3000	80.7	5.78	.00452	3.443	1.225	.74	35.9	.0547	1.42
	2667	54.3	5.01	.00429	3.315	1.225	.70	19.8	.0712	1.41
	2232	30.5	4.03	.00397	3.122	1.225	.65	13.4	.1063	1.43
	1800	16.0	3.09	.00365	2.888	1.225	.56	8.85	.170	1.50
S-142-N	3000	90.3	5.78	.00452	3.28	1.213	.74	27.9	.0504	1.41
S-153-H	2667	243.8	5.01	.00429	4.33	1.225	.72	111	.0157	1.72
	2478	184.1	4.58	.00416	3.65	1.225	.68	80	.0173	1.58
	2232	133.3	4.03	.00397	2.65	1.225	.64	51.6	.028	1.45
S-140-Ar	3000	33.5	70.4	.000393	2.98	1.20	1.00	11.9	.0114	1.36
	2232	15.0	49.4	.000346	2.37	1.20	1.00	69.4	.0192	1.33
	1973	11.23	42.6	.000329	2.22	1.20	1.00	59.3	.0231	1.36
59L	3000	13.15	3.31	.000247	4.01	1.35	.79	90	.0165‡	1.48
80S	2980	11.07	3.04	.000331	3.42	1.33	.92	52	.0290†	1.51

‡ *Descriptions of these lamps follow:*

Lamp	Filament shape	Filament diameter	Dimensions length	Atmosphere	Cooling due to supports
A-33	Straight wire	0.258 mm.	10.85 cm.	Vacuo	None.
S-142-Ar	Straight wire	0.134	8.5	A at 600 mm.	Present.
S-142-N	Straight wire	0.134	8.5	N at 600 mm.	Present.
S-153-H	Very openly coiled wire	0.134	8.5	H at 600 mm.	Present.
S-140-Ar	Straight wire	0.039	8.2	A at 600 mm.	Present.
59L	Very openly coiled ribbon	0.021 0.19	1.65	A at 600 mm.	Present.
80S	Very openly coiled wire	0.083	1.65	N at 600 mm.	Present.

‡ Average of two observations.
† Average of six observations.

Most of the data and discussions herein have referred to filaments of a definite size. But now, with a knowledge of the approximate constancy expressed in equation (16), of the life of a filament as a function of its temperature and of its surrounding atmosphere, and of the gas losses in different gases as a function of the filament dimensions, it is possible to determine the flashing speeds of any sized filament for probable conditions of operation. Thus Table IV gives first the characteristics of a single filament of tungsten operated in various atmospheres at a fixed temperature, and, second, the characteristics of varying sized filaments in the same atmospheres operated under conditions to produce the same luminous flux, the same average life and the same specified voltage. The computations involved while simple in theory are quite tedious. Of course the exactness of the values recorded depends upon the correctness with which the relations used represent facts. Inasmuch as the signalling type of incandescent lamp differs greatly in fundamental principles of construction from ordinary commercial lamps, it naturally follows that much of the data upon which Table IV is based has not been subjected to repeated thorough tests. To illustrate, considerations of speed and of covering a desired field when used with a mirror for directing the flux into a beam, may require very open coils of the filament in the signal lamp in contrast with the tightly closed coils of ordinary lamps. The effect of this on gas-loss data is evident:

TABLE IV.

Characteristics of Lamps Containing Tungsten Filaments in Various Atmospheres Computed for Conditions—(A) filament dimensions and maximum temperature constant; (B) lamp voltage, luminous flux and life constant.

Condition	*A*				*B*			
Atmosphere	Vacuum	*A* at 600 mm.	*N* at 600 mm.	*H* at 600 mm.	Vacuum	*A* at 600 mm.	*N* at 600 mm.	*H* at 600 mm.
Temperature in degrees K. . .	2800	2800	2800	2800	2725	3070	3050	2990
Filament length in centimeters	8.24	8.24	8.24	8.24	6.21	2.96	2.90	2.16
Filament diameter in mm. . .	0.134	0.134	0.134	0.134	0.098	0.073	0.079	0.134
Voltage	14.65	18.45	19.7	39.55	12	12	12	12
Wattage	40.4	64.0	73.0	294	19.7	19.8	23.8	100
Current in amperes	2.755	3.47	3.70	7.44	1.64	1.65	1.98	8.3
Luminous flux in lumens	747	747	747	747	322	322	322	322
Efficiency in $\frac{\text{lumens}}{\text{watt}}$	18.5	11.7	10.4	2.54	16.35	16.3	13.5	3.22
$\frac{E_a}{E_v}$	1.00	1.58	1.81	7.3	1.00	1.66	1.95	7.67
Life in hours . . .	12.7	1110	890	254	25	25	25	25
a	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22
β	4.48	3.37	3.42	4.79	4.51	3.21	3.42	5.40
C in $\frac{\text{degrees}}{\text{joules}}$ . . .	.00439	.00439	.00439	.00439	.00173	.00485	.00557	.00109
Q in $\frac{1}{\text{sec.}}$	18.7	2.39	27.6	144	23.9	59.8	65.0	203
$Q(t_{.7}-t_{.2})$	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
$(t_{.7}-t_{.2})$ in sec.	.076	.059	.052	.010	.059	.024	.022	.0070

the effect on life considerations, while not so evident, is possibly just as real.

The writer has assumed in computing results given in Table IV that the life of very open coiled or straight filament lamps to depend solely on the rate of vaporization, as is the case for commercial, straight-filament, vacuum lamps. A meagre reference by Mackay [7] on the relative decrease in the vaporization of tungsten in a nitrogen atmosphere, some data obtained in the Research Laboratory at Schenectady on a comparison between argon-filled and nitrogen-filled lamps, and some simple life tests conducted by the writer's colleague, Dr. C. F. Lorenz, have led the writer to conclude that atmospheres of nitrogen and of commercial argon at 600 mm. pressure reduce the rates of vaporization of tungsten filaments immersed in them to respectively about one-seventieth and one-ninetieth of the rate in vacuo. Or what is the same, the lives of lamps with filaments immersed in these atmospheres will be about 70 and 90 times as long as the lives of lamps with filaments in vacuo. As to the life of a tungsten filament in a hydrogen atmosphere, there is much greater uncertainty. Little is known beyond the fact that it is much less than that for the same filament at the same temperature in argon or nitrogen. Assuming the rate of vaporization to depend on the diffusion of the tungsten vapor away from the filament, the application of the diffusion theory due to Stefan and Winkelmann,[8] leads to a life in hydrogen equal to about two-ninths of that in argon. We shall probably not be far from the truth by assuming, as we have here, the life of a given filament at a given temperature in vacuo, in argon, in nitrogen, and in hydrogen to vary as 1 : 90 : 70 : 20. For the variation in the rate of vaporization of tungsten in vacuo with temperature, the results of the classic investigation of Langmuir's [9] corrected to the scale of temperature [10] now generally accepted have been used. His results thus corrected are given fairly closely by the equation

$$\log m = 21.56 - \frac{47570}{T} - 3.30 \log T \tag{17}$$

where m represents the rate of vaporization in grams per cm.^{2} per second. This is connected with actual life data through the commercial experience that the 60-watt, 110-volt, vacuum lamp—diameter of 0.050 mm.—at 2440° K has a life of 1000 hours.[11]

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[7] *Trans. I. E. S.*, Sept., 1914, p. 745.

[8] Winkelmann, "Handbuck der Physik," I, p. 1429.

[9] *Phys. Rev.*, 2, p. 329, 1913; *Phys. Rev.*, 10, p. 377, 1917.

[10] *Gen. Elec. Rev.*, 20, p. 819, 1917.

For the gas losses from small filaments for use in compiling Table IV, the writer has taken his own data. Defining E as the rate of dissipation of energy per unit of surface area and thus including gas losses together with radiation, it has been found that the results obtained may be expressed with considerable exactness over the temperature range 1800° K to 3000° K by empirical formulæ of the type.

$$E = A + B\,(\log T - 3.3) + C\,(\log T - 3.3)^2 \qquad (18)$$

The constants A, B and C for a given atmosphere depend on the diameter of the filament. Values for a filament diameter of 0.134 mm. are given in Table V for various atmospheres. Given E as a function of T for one filament diameter for a given atmosphere, a corresponding value for a filament with another diameter in the same atmosphere may be readily obtained by the following empirical relation which holds fairly well for filaments varying in diameter from 0.03 mm. to 0.3 mm.

TABLE V.

Values of the Constants A, B and C of Equation (18) Consistent with Expressing E in Watts per Square Centimetre for a 0.134 mm. Cylindrical Tungsten Wire in Various Atmospheres. Due to Disregarding the Thermal Expansion of the Filament, E is Really Expressed in Watts per Square Centimetre of Filament Surface as Measured at Room Temperature.

Atmosphere	A	B	C
Vacuum	1.379	4.87	1.40
Argon (commercial) at 600 mm. pressure	1.792	3.00	1.25
Nitrogen at 600 mm. pressure	1.859	2.83	2.00
Hydrogen at 600 mm. pressure	2.458	1.61	10.8

$$\frac{\left[\dfrac{E_a}{E_v} - 1\right]_1}{\left[\dfrac{E_a}{E_v} - 1\right]_2} = \left[\frac{d_2}{d_1}\right]^x \qquad (19)$$

where E_a and E_v correspond respectively to a filament in a gaseous atmosphere and in a vacuum and d the filament diameter. For argon and nitrogen x approximates 0.70 for hydrogen 0.75. Equation (19) states in general terms that the gas losses vary inversely as the 0.7 or 0.75 power of the filament diameters.

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[11] This in reality represents a rated life which is noticeably less than the experienced life. No material error in argument is introduced by this assumption of equality.

Other necessary data [12] used in compiling Table IV are well known, or are such as may be obtained from a consideration of what has been given already. The cooling effects of filament supports, which may be considerable in very low-voltage lamps, have been ignored here. It is probable that the values of $(t_{.7}-t_{.2})$ computed for the hydrogen lamps are too small because of ionization effects.

A study of Table IV suggests certain general laws applicable to flashing signal lamps which, while not proven, may be shown to be true.

(1) For a given filament operated in various gases, including in vacuo at a fixed maximum temperature, the flashing speed is greatest in that lamp for which the gas loss is greatest.

(2) For cylindrical filament lamps of the same open construction possessing the same luminous flux and life on a specified voltage, the flashing speed is the greatest in that lamp for which the gas loss is greatest.

(3) For cylindrical filament lamps of the same open construction possessing the same luminous flux and same life when operated at some fixed voltage, the efficiency of the vacuum lamp is less than that of the gas-filled lamp for large sized filaments. The reverse is true for small-sized filaments. In condition *B*, Table IV, the efficiency of the vacuum lamp is greater than that of the nitrogen or the hydrogen lamps, and very nearly the same as that of the argon lamp. For a slightly larger filament the reverse would be true for the argon lamp.

(4) For cylindrical filament lamps of the same open construction possessing the same luminous flux and the same life on a specified voltage, the filament is shortest in the lamp possessing the greatest gas loss. This consideration is of importance in lamps which are used with mirrors or lenses to give intensified beams, in that the longer the filament the more effectively may one cover a certain field or area containing the observer to whom signals are sent.

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[12] Worthing: *Phys. Rev.*, **10**, p. 377, 1917; **12**, p. 199, 1918; *Bul. A. I. M. and M. E.*, Sept., 1919; Hyde, G., *E. Rev.*, **20**, p. 819, 1917; Hyde, Cady and Forsythe, *Phys. Rev.*, **10**, p. 819, 1917.

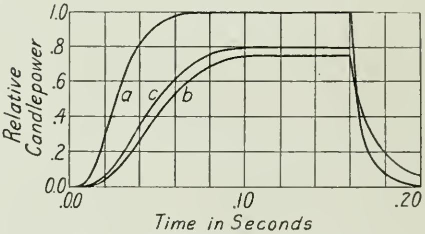
(5) For cylindrical filament lamps of the same open construction possessing the same luminous flux and the same life on a specified voltage, the temperature is lowest in the vacuum lamp and highest in that gas-filled lamp which has the least gas loss. This may be of importance where the color of the light is a factor.

RIBBON FILAMENTS VS. WIRE FILAMENTS.

For equal radiating surfaces a ribbon filament possesses a much less mass of material to be heated than does an equivalent wire filament and therefore will inherently respond the more rapidly on flashing. The flashing speed of a given ribbon filament in vacuo is quite closely equal to that of a wire filament whose diameter is twice the thickness of the ribbon, as follows directly from considering the ratios of the surfaces of the filaments to their masses. Lack of actual equality in gas-filled lamps is due to a difference in gas loss. The great desirability of a ribbon filament in signal lamp construction depends on the fact that through thinness any desired flashing speed is obtainable and that through variations in width any desired current-carrying capacity. A ribbon filament combines the current-carrying capacity of a large wire filament with the high speed of a small wire filament. Contrasting wire and ribbon filaments of the same current-carrying capacity operated at the same temperature. We find that considerations of life are unfavorable to the ribbon filament. Vaporization of the filament material at a given rate in a given length of time produces a greater relative change in the mass of the ribbon filament than in that of the equivalent wire filament. We therefore expect to operate the ribbon filament at a reduced temperature. However, as an offset to this, the ribbon form may possibly be favored somewhat in the vaporization rate and in the gas loss due to the lines of flow of vapor and of heat being on the whole parallel near the ribbon filament in contrast to the spreading lines of flow about the wire filament. A few careful measurements which have been made indicate an appreciable factor in favor of the ribbon form in cutting down gas losses. However, the great advantage of a ribbon form, considering everything, is the possibility offered by the ribbon filament in increased efficiency without loss of speed by changing from a gas with a great gas loss to one with a small gas loss. Thus it was felt, in planning to meet the demands for a 6-volt, 2-ampere lamp for warfare, that a proposed lamp containing a wire filament should be filled with nitrogen, while the ribbon filament lamp might be filled with argon. Flashing speeds for preliminary lamps of these two types from which the final selection was made, No. 26L, No. 59L, and No. 80S, which illustrate these deductions have already been referred to in Tables I and III.

No speed tests were carried out with 6-volt, 2-ampere signal lamps with ribbon and wire filaments operating at temperatures such as to yield a 25-hour life. However, starting with the curve of Fig. 3 and the speed data of 59L and 80S, given in Table III, it is not difficult to tell what such curves will be like. Fig. 7 shows what is to be expected for the two types as well as for a ribbon in vacuo. (Due to neglecting end-coolings in Tables IV, some discrepancies will be found between the data there given and that represented in this figure.) The advantage of the ribbon filament in argon over the wire filament in nitrogen in flashing speed is seen to be approximately 1.6, in luminous efficiency 1.25. The reason for the actual selection of lamps with ribbon filaments in argon for warfare signalling is apparent.

Fig. 7,



Expected speed of performance for three 6-volt, 2-ampere tungsten-filament signal lamps operated at temperatures corresponding to about 25 hours of life. *a.* 0.021 mm. ribbon filament in an argon atmosphere. *b.* Ribbon filament of the same thickness in vacuo. *c.* 0.084 mm. wire filament in a nitrogen atmosphere. The cooling curve for the wire-filament lamp (not shown) lies generally near the cooling curve of (*a*). The corresponding maximum temperatures are approximately 3020°K., 2660°K. and 3050°K.

It is interesting to note certain tests conducted by the writer's colleague, W. E. Forsythe.[13] Using sometimes a special sectored disk, so cut as to give at will various combinations of dot-and-dash signals when rotated before a steady light source, and at other times a special commutator for producing at will any one of the same combinations of dots and dashes by flashing a signal lamp, he found, using 6-volt, 2-ampere lamps, (1) that the maximum speed of reception of signals using signal lamps with ribbon filaments in argon did not differ noticeably from that using the rotating sector and a steady source, which presumably offers the maximum possible speed; (2) that the speeds of reception of signals were noticeably greater when using lamps with ribbon filaments in argon than when using lamps with the same filaments in vacuo; and (3) that the speeds of reception of signals were noticeably greater—roughly of the order that might be expected from Fig. 7—when using lamps with ribbon filaments in argon than when using lamps with wire filaments in nitrogen.

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[13] *Phys. Rev.*, 16, p. 62, 1920.

CONCLUSION.

The selection of a lamp for signalling purposes which shall have a given life and luminous flux at a specified voltage naturally depends on various factors such as the rapidity of the flash, the size and the intensity of the beam from the unit of which the lamp is a part, the luminous efficiency of the lamp either for all visible wave-lengths or for some limited region of the spectrum, and the ruggedness of structure. Certain factors will naturally be of greater importance than others and may be decisive in making a selection. So far as speed and efficiency are concerned, what has been said indicates clearly that a lamp containing a ribbon filament in argon represents the preferred type of construction for use in a 6-volt, 2-ampere signalling unit. In a future paper entitled "The Theory of Signalling Units Employing Incandescent Lamp Sources" the author intends to discuss the characteristics of the beam from a signalling unit.

The writer is greatly indebted to Mr. Kenneth Moorhead who has assisted throughout the investigations, particularly in the making of the speed measurements.

Cleveland, Ohio,
November, 1920.

American Beet Sugar. (*Sugar*, December, 1920, p. 690.)—American beet sugar is expected to harvest a larger California crop this year, according to present indications. Its coast campaign has just been completed with satisfactory results and about 20 per cent. of its full outturn produced in the Rocky Mountain States, yielding 100,000 bags more than in 1919–1920. Indications are that its total output this year will be between 1,400,000 and 1,500,000 bags, against 1,077,000 for the previous campaign.

Progress in Commercial Aviation.—In an address before the Society of Automobile Engineers, in New York, on Tuesday, January 11, 1921, Grover C. Loening asserted that misdirected aviation development is largely responsible for the present condition of aeronautics in the United States. On the basis of the experience of the past few years, it appeared that the supposed advantages of multi-engined and all-metal planes have been important causes of false leads in the development of commercial service. Mr. Loening claimed that the useful loads per horsepower are almost as great in a single-engined plane as in one equipped with two or more engines. He declared that it is a mistake to assume that a duplication of engines gives greater safety from engine failure, since most of the causes of failure, such as weather conditions, sleet and ice, would stop all the motors. He also said that it is very rare that the engine fails in itself. Something usually fails in the gas line or the water line. Engines applicable to war-planes are not suitable for commercial planes. The following were given as desirable features in the development of the power-plant in commercial planes. (1) Muffling devices. (2) Geared-down engines, or, better still, slower running engines to improve the propeller power, particularly in starting and climbing speeds. (3) Further development of the reversible pitch propeller.

Before the same society Professor E. P. Warner presented a paper which included some statistics of the passenger service between England and the continent. In the first eleven months of the service there was a total of twenty-four accidents, in four of which one or more persons were killed. The pilot was killed in each case, but only one passenger in the entire period. The average death-rate for pilots was one for every 2410 hours in the air. The passenger rate is one death for every 67,000 carried, and taking into consideration the fact that the average speed is 90 m.p.h., one fatality for every 1,640,000 passenger miles.

H. L.

Prickly Pear Oil.—In the manufacture of an edible jelly, known as *queso*, from the fruit of the prickly pear, the seeds are discarded as waste. These seeds are rich in oil; the seeds of a variety of white prickly pear, known as *tuna blaca de huerta*, contained 10.89 per cent. of oil. By extraction of the seeds with petroleum ether, the oil was obtained as a greenish-yellow, odorless, somewhat viscous oil. Among its constants were: Acid value, 3.09; saponification number, 189.5; iodine number, 116.3; Reichert Meissl number, 2.8; Hehner number, 93.81. From the results of his study, S. LOMANITZ (*Journal Ind. and Eng. Chem.*, 1920, xii, 1175) concludes that this oil should probably be placed among the semi-drying oils, and might be used in the arts if produced in sufficient quantity.

J. S. H.

THE APPARENT FORM OF THE SKY-VAULT.*

BY

M. LUCKIESH.

Director of Applied Science, Nela Research Laboratories.

The apparent form of the vault of the sky has attracted the attention of many investigators for centuries. Alhazen, an Arab astronomer, wrote about it in the tenth century, and since that time hundreds of memoirs upon the subject have appeared in technical and scientific literature. Notwithstanding all the investigations there is no general agreement as to the cause for the illusion of a flattened dome of sky; however, there is a general agreement that the vault of the sky usually appears somewhat flattened. Although the evidence which the writer will submit may not be conclusive, in his opinion it points very strongly toward the chief cause of the illusion.

Before presenting this evidence it may be of interest to discuss some of the pertinent details and some of the results obtained by other investigators. Dember and Uibe assumed the apparent shape of the sky-vault to be a part of a sphere (justifying this assumption to their own satisfaction) and obtained estimates of the apparent depression at the zenith. They estimated the middle point of the arc from the zenith to the horizon and then measured the angular altitude of that point. They found that the degree of clearness of the sky has considerable influence upon the apparent height and they state that the sky appears higher in the subtropics than in Germany. On very clear nights they found that the shape of the sky-vault differed little from that of a hemisphere. They concluded that the phenomenon is apparently due to optical conditions of the atmosphere which have not been determined.

Nearly two centuries ago Robert Smith and his colleagues concluded that the sky appeared about three times as far away at the horizon as at the zenith. They also determined the relative apparent variation of the size of the sun with altitude and suggested that the illusion of greater size of the sun near the horizon was due to the illusion of the flattened dome of the sky. They also made similar measurements for the moon and certain constellations. The apparent size of these heavenly bodies according to their measurements was three or four times greater at the horizon than at the zenith.

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* Communicated by the Author.

Photographs have been published of the sun and of the moon at various altitudes which prove that the apparent enlargement of these heavenly bodies near the horizon is an illusion. The writer recently confirmed this by recording the paths of these bodies on panchromatic photographic plates, using a red filter to minimize the effect of the selective absorption of the atmosphere.

The appearance of the flattened vault of the sky is held by some to account for the apparent enlargement of the sun, moon, and constellations near the horizon. That is, they appear more distant at the horizon and we instinctively appraise them as being larger than when they are at higher altitudes. Aerial perspective is often considered to be a contributing factor. Distance is often estimated by the definition and color of objects seen through great depths of air. Distant objects are blurred by the irregular refraction of the light-rays through non-homogeneous atmosphere. They are also obscured to some degree by the veil of brightness due to the illuminated dust, smoke, etc. They are also tinted by the superposition of a tinted atmosphere. Thus we have "dim distance," "blue peaks," "azure depths of sky," etc., represented in photographs, paintings, and writings.

We judge unknown size by estimated distance and unknown distance by estimated size. If we unconsciously think of the path of heavenly bodies as being along the surface of a flattened vault of sky it is obvious that we must unconsciously think of them being farther away at the horizon than at the zenith. Therefore, the necessary compensation must be obtained in some manner and it may be that it manifests itself in an appearance of greater size at the horizon. Certainly these heavenly bodies universally appear considerably larger at the horizon than at higher altitudes. It is also certain that this is largely if not entirely an illusion.

The writer has had an excellent opportunity to study the apparent form of the sky-vault during many high-altitude flights in airplanes. The brevity of the interval of time that elapsed between views at the ground, in the earth-haze and low-cloud region, and at high altitudes where the sky was dark, was an ideal condition for making these observations.

The sky is bright, due to scattering of light by actual particles of solid matter and moisture and possibly by molecules of gas. If the region above the earth was a void as it is in interstellar space, the sky would be black in the daytime and the sun would appear more piercingly bright. Shadows would generally be very harsh and dark. Lack of optical homogeneity of the atmosphere due to varying refractive index is likely to be partially responsible for the brightness of the sky. Usually a prominent layer of haze about a mile in thickness (although this varies considerably) lies next to the surface of the earth. The top of this haze is fairly well-defined and cumulus clouds project above it like partially submerged icebergs. If there are no high clouds present the sky when seen above the earth-haze is deep blue, but still appears fairly bright near the horizon. After an altitude of four or five miles is reached most of this thin upper haze is left behind, and the sky is often very dark and the sun is piercingly bright. Usually there is little or no bright haze adjacent to the sun at these high altitudes as is commonly seen from the earth's surface.

With these brief glimpses of the aspects of the sky as one ascends, let us resume our view of the sky from the earth's surface when cumulus clouds are present. The bases of these clouds are fairly flat because they are at the level where the air is saturated. This level varies in altitude from three to five thousand feet. These clouds, if they cover the sky completely, form a flat ceiling, but the latter appears to bend down at the horizon. When cumulus clouds are present here and there they appear like a few stray pieces of fleecy wool overhead, but toward the horizon they appear *en echelon,* stepping down toward the earth and meeting it at a distance which appears many times greater than their vertical distance overhead. This can account for the appearance of a very much flattened vault of sky.

This apparent shape persists to some degree even in clear weather, perhaps partially on account of the degradation of color toward the horizon but chiefly to the variation in brightness. Usually the sky is considerably brighter near the horizon than at the zenith, and the latter being darker appears to hang low.

Now let us ascend rapidly in an airplane or a balloon on a day when the illusion of the flattened sky-vault is quite powerful, such as on a day when many cumulus clouds are in the sky. We leave the earth with a strong impression of a flattened vault of clouds and haze above us. We see it bending to meet the horizon on all sides. In a few minutes we are on the same level as the clouds and low-lying haze and we are surprised to find these are levels and do not comprise a vaulted roof. Notwithstanding the many flights which the writer has taken above this level, he still experiences a feeling of mild surprise at this revelation. This testifies to the persistence and strength of the illusion.

After we have nosed our way up through the low cloud-and-haze level, we find another horizon and another sky-vault. Assuming there are no upper clouds present, we see a fairly dark blue sky at the zenith but which brightens and becomes less saturated in color toward the haze-horizon. Under such conditions the sky-vault now appears more like a hemisphere than the very much flattened vault it appeared to be when viewed a few minutes before from the earth. However, it still appears somewhat flattened at the zenith. But as we continue to climb we leave more and more of the "sky" behind us. The sky above grows darker gradually until at an altitude of four miles it may be only one-fifth as bright as it is on an unusually clear day as seen from the earth. Now it appears like a hemispherical dome and really there are times when one is not conscious even of the dome. That is, there are times when this deep blue is merely an infinite space of nothingness.

In the course of a few minutes we have seen two sky-vaults, and the brevity of this interval permits almost a direct comparison of the two. Such a comparison is unobtainable by any other means than aerial travel. The suddenness of the transition from the powerful illusion of a flattened vault of sky to a much weaker illusion of a nearly hemispherical dome is very convincing. After flying in the upper region and viewing the level sea of haze meeting the horizon in an unbroken circle, let us suddenly dive downward through this level. In a minute we are again viewing the haze-and-cloud level from the lower side and are seeing the clouds again *en echelon,* stepping down to the earth level and meeting at the horizon.

The writer has repeated these experiences many times under vastly different sky-conditions and always with the same impressions. However, the apparent flattening of the sky-vault varies considerably, depending upon the conditions of clearness, haziness, or cloudiness. These variations provide opportunities for studying this illusion under many conditions, but best of all is the kaleidoscopic change witnessed during a rapid ascent and descent. The writer is thoroughly convinced that the apparent flattening of the sky-vault is due to such conditions as the appearance of clouds *en echelon*, the gradual variation in brightness and color of the sky from the zenith to the horizon, and the apparent lowness of a darker zenith. A very dark uniformly overcast sky, a uniformly bright, hazy sky, and a uniform blue sky as seen at high altitudes, approach in appearance a·hemispherical vault. An appearance of flattening is encountered on clear days when there is a gradual change in the brightness and color of the sky. The appearance of greatest flattening is found on cloudy days such as those on which many small cumulus clouds are present.

That the apparent enlargement of heavenly bodies near the horizon is almost entirely, if not entirely, an illusion, appears to be fully proved. These striking experiences with the persistency and powerfulness of the illusion of the flattened sky-vault lead the author to believe that the apparent enlargement of heavenly bodies is at least partially due to it. But in discussing this other illusion many peculiar conditions and prejudices must be taken into account. For example, if various persons are asked to give an idea of the size of the disk of the sun or moon, their answers would vary usually with the head of barrel as a maximum. However, the size of a tree at the sky-line might be given as thirty feet. At the horizon we instinctively compare the size of the sun, moon, and constellations with hills, trees, houses, and other objects (seen in front of them), but when the former are high toward the zenith in the empty sky we may judge them in their isolated position to be nearer, hence smaller.

Preparation of Pure Carbon Dioxide.—Robert Crosbie Farmer, of the Royal Arsenal, Woolwich, prepares carbon dioxide completely free from air by the reaction between potassium hydrogen carbonate and sulphuric acid. Carbon dioxide is passed through a solution of potassium hydrogen carbonate (300 grams to the litre) and also through a solution of sulphuric acid (120 c.c. diluted to 1 litre); the solutions are thus rendered free from dissolved air; they are then caused to react in an air-free vessel; and pure carbon dioxide, entirely free from air, is obtained. The product is so pure that it gives practically no gaseous residue on absorption with potassium hydroxide solution (*Journal of the Chemical Society*, 1920, cxvii, 1446–1447).

J. S. H.

Results and Analysis of Magnetic Observations During Solar Eclipse, May 29, 1919. LOUIS A. BAUER. (*Terrestrial Magnetism and Atmospheric Electricity*, September, 1920.)—This eclipse afforded favorable opportunities for studying "solar-eclipse magnetic variation" not only near the magnetic equator but also in both magnetic hemispheres. After the observations then made "there cannot be any doubt that the earth's magnetic condition is subject to an appreciable magnetic variation during a solar eclipse. Indeed, the greater surprise would be, in view of the existence of the solar-diurnal and lunar magnetic variations, if the gradual withdrawal and restoration of solar radiation during a solar eclipse, in greater or less degree, over nearly one-half of the daylight portion of the earth, did not give rise to a magnetic variation."

Happily, May 28th, 29th, and 30th were magnetically calm, so that the effects of the eclipse were projected upon a colorless background. The maximum change of declination was observed at Sobral, Brazil, where the compass needle moved almost three minutes of arc farther toward the east. The maximum change of inclination was at Cape Palmas, Liberia, where the north end of the dipping needle fell two and one-half minutes further below to the horizontal. The changes in declination and horizontal intensity were about such as would have been produced by a north magnetic pole located in the shadow cone cast by the moon.

G. F. S.

Gypsum Deposits in the United States. (*U. S. Geological Survey Press Bulletin No. 460*, December, 1920.)—A bulletin describing the gypsum deposits in the United States has just been issued by the Survey. Gypsum is the rock used for making plaster of Paris and hard wall plaster, and it is also an ingredient of Portland cement and is used as a fertilizer. The bulletin shows that gypsum is distributed from New York to California and from Michigan to Texas. The deposits in some States are so small that they may be worked out in a few years; those in other States, like Wyoming and New Mexico, consist of thick beds that crop out at the surface for hundreds of miles and that are seemingly inexhaustible. The bulletin contains 325 pages and many illustrations and includes a technical discussion of the physical and chemical properties of gypsum, a classification of the deposits by origin, a history of the gypsum industry in the United States, and a brief description of processes of mining and milling, as well as a bibliography, but it consists principally of descriptions of the deposits, by States, written by State geologists and others who are thoroughly familiar with them. The book, which is published as Bulletin 697 of the U. S. Geological Survey, was compiled and in part written by R. W. Stone, a geologist who has made a special study of gypsum.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE MAGNETIC RELUCTIVITY RELATIONSHIP AS RELATED TO CERTAIN STRUCTURES OF AN EUTECTOID CARBON STEEL.[1]

By C. Nusbaum, W. L. Cheney and H. Scott.

[ABSTRACT.]

THE magnetic reluctivity (ρ), defined as the ratio of the magnetizing force to the induction, has been shown by Kennelly to be related to the magnetizing force by the relationship

$$\rho = \alpha + \beta H, \qquad (1)$$

but for high inductions this has to be modified to

$$\rho_0 = \frac{H}{B-H} = \alpha + \beta H, \qquad (2)$$

where ρ_0 is the metallic reluctivity and $B-H$ is the metallic induction or flux carried only by the molecules of the metal. For pure and well annealed materials the reluctivity line is a straight line, while in the more or less impure commercial materials the reluctivity line, though approximately a straight one, has generally a point where its slope changes. Since the change in the slope of the line is in general greater with the increase in impurity of the material, the cause is evidently a lack of homogeneity, *i.e.*, the presence in the substance as aggregates or inglomerates of materials of different magnetic characteristics. Although the arrangement of the constituents in a carbon steel is generally a random one, it may be considered as combinations of any of the three simple arrangements, *viz.:* (*a*) the parallel, (*b*) the series, and (*c*) the spheroidal.

In the experiments described in the present paper, two specimens of an eutéctoid carbon steel (0.85 per cent. carbon) were selected and turned down to a uniform diameter of approximately

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* Communicated by the Director.

[1] Scientific Paper No. 404.

7 mm. Each of these specimens was quenched from 800° C., one in oil, the other in water, and then carefully ground down to 6 mm. Each specimen was then cut in halves designated A and B, which were then drawn alternately to increasingly higher temperatures up to 700° C. Normal induction curves up to values of the magnetizing force as high as 2500 gausses were determined after each operation.

Curves for a few of these heat treatments are shown. Other magnetic properties shown graphically are (*a*) the values of the induction for constant values of the magnetizing force as plotted against the drawing temperatures, (*b*) the reciprocals of the susceptibility (4π times the reluctivity) as plotted against the magnetizing forces, (*c*) the value of the saturation intensity of the magnetization as plotted against the drawing temperatures, and (*d*) the values of the "magnetic hardness" as plotted against the drawing temperatures. Referring to equation (2), the values of the saturation intensity of magnetization are equal to $\frac{1}{4\pi\beta}$, *i.e.*, the reciprocal of the slope of the reciprocal of susceptibility line. The values of the "magnetic hardness" are the values of α, *i.e.*, the intercept on the axis of ordinates.

These two characteristics are those with which this paper is most concerned, since they show more than any others the transformations which take place in the steel as a result of the heat treatment. It is found that in a region included by the quenched condition and a drawing temperature of 230° C., in which the specimen is known to be martinsitic in structure, there is a distinct bend in the reluctivity line, and consequently there are two values of the saturation intensity of magnetization and the "magnetic hardness" as calculated from the upper and lower portions of the reluctivity line. In the range of drawing temperatures bounded by 230° C. and 470° C., in which the steel is troostitic, the reluctivity line has but one slope, hence the saturation intensity of magnetization and the "magnetic hardness" each have but one value for a given drawing temperature and the material is magnetically homogeneous. Beyond 470° C. the reluctivity line again has a bend and the material is non-homogeneous, this inhomogeneity being due to the increasing size of the aggregates and to their approaching stratification.

ANNUAL REPORT OF THE DIRECTOR OF THE BUREAU OF STANDARDS.[2]

[ABSTRACT.]

THE annual report of the Director of the Bureau of Standards for the fiscal year ended June 30, 1920, contains some valuable and interesting information.

During the year the work of the Bureau has undergone readjustment of staff and work. Naturally the research for the military departments has considerably diminished, though not as much as had been anticipated; while work for the industries has increased to a very great extent. During the year the Bureau completed 106,899 tests of weights, measures, measuring instruments, mechanical appliances and materials.

During the war American manufacturers were brought into closer contact with the Bureau than ever before, and this relationship has continued, with the result that many industries now look to the Bureau for aid in the solution of their problems. The volume of research results made available for the industries is evidenced by the 106 new publications issued during the year giving the results of the scientific and technical investigations and researches of the Bureau.

The regular appropriations of the Bureau for the fiscal year 1920 amounted to $1,397,260; and additional items of $495,000 were carried in the first Deficiency Appropriation Act, making a total of $1,892,260. Some reimbursements were received from other departments for coöperative researches, although not in the same volume as during the war period. The total disbursements during the year amounted to $1,686,345.56.

The staff of the Bureau included 382 statutory employees and about 600 engaged in research investigations specially authorized by Congress. Of this number, 211 were scientific positions, 55 office assistants, 76 engaged in the operation of plant, and 40 in construction work.

The salaries paid to the employees of the Bureau are still inadequate, and because the Bureau can not successfully compete with the salaries paid by industrial concerns, there was an excessively large labor turn-over during the fiscal year. It is hoped that this condition will be improved during the coming year, as it is extremely difficult to maintain high-grade scientific work on a first-class basis with a constantly changing personnel.

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[2] Miscellaneous Publication No. 44.

The work of research institutions such as the Bureau of Standards is of unusual importance at present because American industries have taken up the manufacture of products which before the war were produced entirely in Europe. As these industries are now engaged in work of this sort on quite an extensive scale, it is essential that they be given every chance to meet fairly the foreign competition which will undoubtedly develop. In order to do this, it is necessary that they be kept informed of all the latest scientific developments in manufacturing processes. Research work of this kind can generally be carried out on a large scale only by some centrally located and well-equipped institution, such as the Bureau of Standards.

BUYING COMMODITIES BY WEIGHT OR MEASURE.[3]

[ABSTRACT.]

The material in this publication is a reprint from Circular No. 55. All the information in that Circular especially of use in the purchase of ordinary commodities has been included here. The publication explains the Bureau's interest in this subject and gives briefly some of the results of the investigation made by the Bureau upon commercial weights and measures throughout the United States. The best methods of buying commodities and of checking the purchases made are detailed and in this connection apparatus are described comprising satisfactory household test sets and their use in determining whether or not full weight and measures are being received. Abstracts of some useful Federal and State laws are given. One section is devoted to kitchen measuring appliances and capacity units employed. The appendix contains various tables of weights and measures.

STANDARDS FOR GAS SERVICE.[4]

[ABSTRACT.]

The large demand for the three earlier editions of Circular 32, "Standards for Gas Service," and the favorable comment which they have called forth have clearly demonstrated the value of a publication of this kind. Economic conditions, gas-making practice, and the purposes for which gas is used change from time to time with the development of the industry, and with such changes should come changes in the various state and city regulations. To be most valuable, therefore, a publication such as this must be revised from time to time to take cognizance of these new conditions. The three previous editions of this circular were issued in 1912, 1913, and 1915, respectively. The preparation of the fourth edition has been delayed on account of the increased demands upon the Bureau incident to the war.

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[3] Miscellaneous Publication No. 45.

[4] Circular No. 32, 4th edition.

In this new edition the Bureau presents a very complete résumé of state and city regulations now in force defining gas service, and brings up to date the discussion of technical requirements and the Bureau's recommendations of rules and ordinance forms. In order to take full advantage of the recent experience of members of its staff and of others throughout the United States with whom it has coöperated, it has been found necessary to extend greatly or to wholly rewrite certain sections of this circular. Those who have used the earlier editions are, therefore, urged to note with care the more important portions of the discussion, in order that they may have clearly before them the significance of these additions and changes. It is hoped that this revision will increase the usefulness of the publication.

MEANING OF STANDARDS FOR GAS SERVICE.

In order to insure satisfactory gas service the public authorities have usually found it desirable to establish regulations governing the quality of the gas to be supplied, and setting forth the privileges, duties, and responsibilities of the company in the conduct of its business. These regulations should cover the three general requirements of good service, which are: (1) that gas of satisfactory and reasonably uniform quality and pressure be available to the consumers at all times and that such gas be correctly metered; (2) that the price of gas be reasonable, though adequate to permit the maintenance of the company's equipment at a high state of efficiency and the earning of a fair return on the investment; and (3) that all portions of the municipality or district which are sufficiently populous to warrant it be supplied with gas.

The first of these general requirements defines "Standards for Gas Service," which comprise the conditions which must be defined in respect to heating value, purity, pressure, and measurement of gas, and the relation of the gas company to its customers. These questions receive the principal consideration in this circular. However, the probable effect of such regulations upon the cost and selling price of gas must be carefully considered, for in general any increase in the cost of manufacturing or supplying gas falls ultimately upon the customers. Therefore, only those rules and regulations should be made which really improve the service enough to justify the cost of meeting them.

In the formulation of service rules and in the enforcement of such requirements it should always be borne in mind that these regulations are really a technical specification covering the quality of the commodity and the service to be supplied under a franchise which is in effect a contract with the people. These specifications should not be looked upon as police regulations of the state or the city, but rather as a part of a business arrangement between purveyor and users of gas, and if properly drawn they will protect the interests of both parties to the contract. To do this they must be not only fair and equitable, but also clear and comprehensive, defining precisely and without ambiguity all the important conditions which it is expected the gas company shall meet in furnishing gas service. The fact that the company is likely without requirement to fulfill certain important conditions is not sufficient reason for the omission of these conditions from the rules or ordinance. And, on the other hand, it is not reasonable or fair to the gas company to omit rules which afford it protection against unreasonable demands or unjust criticism.

HEATING VALUE STANDARDS.

Heating value requirements should not only provide for a certain quantity of heat per cubic foot, but should insure to the consumer a gas of such characteristics that its heat may be utilized conveniently and efficiently. Due consideration must be given to the types of equipment and processes of manufacture in most common use, and to the grades of gas-making materials in use or economically available. These conditions may change from time to time, and a heating value correct at the time of adoption may require change later. The gas should be free from excessive quantities of easily condensible hydrocarbon vapors, since its heating value and composition can then be maintained more nearly uniform, and a more satisfactory and efficient service to the consumer will result. Ultimate cost to the consumer is of utmost importance. In fact, heating-value regulations should be so fixed as to promote efficiency and good service, or, as it is often expressed in other words, so that the average consumer will do his cooking, heating, and lighting at the least cost and with the least possible cause for complaint. The determination of the best heating value standard cannot, therefore, be made by the use of an empirical formula or by averaging the results actually obtained at the various plants. It must rather be a matter of engineering judgment based on a knowledge of prevailing conditions.

CANDLEPOWER REQUIREMENTS.

Gas was originally used almost exclusively for open-flame lighting, and naturally, therefore, most of the early requirements as to the quality of the gas related to the amount of light produced in such burners, *i.e.*, to the open-flame candlepower of the gas. However, at the present time, cooking, water heating, mantle lighting, and industrial applications of gas consumed by far the larger percentage of the total gas made, and in these operations it is the heat given out in combustion of the gas that is of importance to the user. Only a few per cent. of the gas distributed in this country is used in open flames, and, in fact, probably not over 2 per cent. of it should be so used, considering only economy to the consumer.

As a result of this change in conditions, heating-value requirements have largely replaced candlepower requirements. In fact, the situation has so changed that there is no longer any justification for the adoption of new candlepower regulations.

RECOMMENDED SPECIFICATION FOR ASPHALT VARNISH.[5]

[ABSTRACT.]

THIS specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 27, 1920. The Committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The

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[5] Circular No. 104.

Committee's draft was submitted to representatives of the paint and varnish industries and careful consideration given to their suggestions.

The specification gives the general requirements as to performance, leaving the question of specific composition an open one so as to permit a wide range of sources for the material. The provisions also include statements as to the methods of sampling, laboratory examination, and preparation of reagents.

This varnish shall be composed of a high grade of asphalt fluxed and blended with properly treated drying oil and thinned to the proper consistency with a volatile solvent. It must be resistant to air, light, lubricating oil, water, and mineral acids of the concentration hereinafter specified, and must meet the following requirements:

Appearance.—Smooth and homogeneous; no livering or stringiness.

Color.—Jet black.

Flash Point (closed-cup).—Not below 30° C. (86° F.).

Action with Linseed Oil.—Varnish must mix freely to a homogeneous mixture with an equal volume of raw linseed oil.

Insoluble in Carbon Bisulphide.—Not more than 1 per cent.

Non-volatile Matter.—Not less than 40 per cent. by weight.

Fatty Matter.—Not less than 20 per cent. of the non-volatile. Must be liquid and not show any rosin by the Liebermann-Storch test.

Set to Touch.—Within 5 hours.

Dry hard and Tough.—Within 24 hours.

Toughness.—Film on metal must withstand rapid bending over a rod 3 mm. (1/8 inch) in diameter.

Working Properties.—Varnish must have good brushing, flowing, covering, and levelling properties.

Resistance to Water.—Dried film must withstand cold water for 18 hours.

Resistance to Oil.—Dried film must withstand lubricating oil for 6 hours.

Resistance to Mineral Acids.—Dried film must withstand action of the following acids for 6 hours: Sulphuric acid, specific gravity 1.3 (about 40 per cent.). Nitric acid, specific gravity 1.22 (about 35 per cent.). Hydrochloric acid, specific gravity 1.09 (about 18 per cent.).

RECOMMENDED SPECIFICATION FOR COMPOSITE THINNER FOR THINNING SEMIPASTE PAINTS WHEN THE USE OF STRAIGHT LINSEED OIL IS NOT JUSTIFIED.[6]

[ABSTRACT.]

This specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 27, 1920. The Committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The Committee's draft was submitted to representatives of the paint and varnish industries and careful consideration given to their suggestions.

The specification gives the general requirements as to performance, leaving the question of specific composition an open one so as to permit a wide range of sources for the material. The provisions also include statements as to the methods of sampling, laboratory examination, and preparation of reagents.

This specification covers a composite thinner which contains in one liquid drying oil, drier, and volatile thinner. The composite thinner must meet the following requirements:

Appearance.—Shall be clear and free from suspended matter and sediment.

Color.—No darker than a solution of 6 g. of potassium dichromate in 100 c.c. pure sulphuric acid of specific gravity 1.84.

Odor.—Not offensive, either in bulk or in its subsequent use in paint mixtures.

Mixing with Linseed Oil.—When mixed in any proportion with pure raw linseed oil meeting the specifications of B. S. Circular 82, the resulting mixture shall be clear and shall show no separation or precipitation on standing 18 hours.

Drying.—When flowed on glass, the composite thinner shall set to touch in not more than 4 hours and dry hard in not more than 6 hours. When mixed with an equal volume of pure raw linseed oil, the resulting mixture when flowed on glass shall set to touch in not more than 6 hours and dry hard in not more than 8 hours.

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[6] Circular No. 102.

Toughness.—The film on glass after baking for 6 hours at 105 to 110° C. (221 to 230° F.) shall be glossy, tough, and elastic.

Non-volatile Matter.—Not less than 50 per cent. by weight.

Acid Number.—Not more than 12, calculated to basis of non-volatile matter.

RECOMMENDED SPECIFICATION FOR SPAR VARNISH.[7]

[ABSTRACT.]

THIS specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization, September 27, 1920. The Committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The Committee's draft was submitted to representatives of the paint and varnish industries and careful consideration given to their suggestions.

The specification gives the general requirements as to performance, leaving the question of specific composition an open one so as to permit a wide range of sources for the material. The provisions also include statements as to the methods of sampling, laboratory examination, and preparation of reagents.

The varnish shall be the best long oil varnish. It must be resistant to air, light, and water. The manufacturer is given wide latitude in the selection of raw materials and processes of manufacture, so that he may produce a varnish of the highest quality. It must meet the following requirements:

Appearance.—Clear and transparent.

Color.—Not darker than a solution of 6 g. of potassium dichromate in 100 c.c. of pure sulphuric acid, specific gravity 1.84.

Flash Point (closed-cup).—Not below 30° C. (85° F.).

Non-volatile Matter.—Not less than 40 per cent. by weight.

Set to Touch.—In not more than 5 hours.

Dry Hard and Tough.—In not more than 24 hours.

Toughness.—Film on metal must stand rapid bending over a rod 3 mm. (1/8 inch) in diameter.

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[7] Circular No. 103.

Working Properties.—Varnish must have good brushing, flowing, covering, and levelling properties.

Water Resistance.—Dried film must withstand cold water for 18 hours and boiling water for 20 minutes without whitening or dulling.

Durability.—The purchaser reserves the right to require that the durability of deliveries must be equal to a brand or sample mutually agreed upon by buyer and seller.

NOTE.—When durability tests are required, such tests will be made on each sample; but in cases where the testing laboratory has previous data on the same brand of varnish, acceptance or rejection of a given sample may be provisionally based on the last completed test of the brand of varnish in question.

RECOMMENDED SPECIFICATION FOR LIQUID PAINT DRIER.[8]

[ABSTRACT.]

THIS specification was prepared under the auspices of the Bureau of Standards by the U. S. Interdepartmental Committee on Paint Specification Standardization September 27, 1920. The Committee consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The Committee's draft was submitted to representatives of the paint and varnish industries and careful consideration given to their suggestions.

The requirements include methods of sampling, laboratory examination, and also basis of purchase.

This specification applies both to straight oil drier—that is, material free from resins or "gums"—and to Japan drier; that is, material containing varnish "gums."

The drier shall be composed of lead, manganese, or cobalt, or a mixture of any of these elements combined with a suitable fatty oil, with or without resins or "gums," and mineral spirits or turpentine, or a mixture of these solvents. It shall be free from sediment and suspended matter. The drier when flowed on metal and baked for 2 hours at 100° C. (212° F.) shall leave an elastic film. The flash point shall be not lower than 30° C. (85° F.) when tested in a closed-cup tester. It shall mix with pure raw linseed oil in the proportion of 1 volume of drier to 19 volumes of oil without curdling, and the resulting mixture when flowed on glass shall dry in not more than 18 hours. When mixed with pure raw linseed oil in the proportion of 1 volume of drier to 8 volumes of oil, the resulting mixture shall be no darker than a solution of 6 g. of potassium dichromate in 100 c.c. of pure sulphuric acid of specific gravity 1.84.

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[8] Circular No. 105.

LIME: DEFINITIONS AND SPECIFICATIONS.[9]

[ABSTRACT.]

LIMESTONES are classed as high-calcium or magnesian according to the ratio of lime to magnesia which they contain. According to their physical structure, they vary from marble to chalk. Crushed stone of various sizes is used for blast-furnace flux, aggregate for concrete and asphalt, ballast, road-metal, sand, whiting, etc. It is also a basic raw material used in the manufacture of cement, glass, pottery, etc.

Agricultural lime, used as a fertilizer, may be ground limestone, quicklime, or hydrated lime.

Quicklime is made by burning limestone. It is used as a building material, as an ingredient of mortar and plaster. Slaked lime is made by adding water to quicklime to form a putty.

Hydrated lime is made by adding just enough water to quicklime to form a dry powder. It is used as a building material instead of quicklime, and also as an addition to cement mortars and concretes.

Both quicklime and hydrated lime are used as basic raw material in the manufacture of paper, sugar, bleaching powder, alkalies, etc.

Air-slaked lime is worthless as a building material and is seldom an article of commerce.

Quicklime is shipped in barrels, holding 180 or 280 pounds net; hydrated lime in paper bags holding 50 pounds.

The quantities of lime required for making plaster and mortar are given, as well as the amount for use as fertilizer. A formula for making whitewash is included.

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[9] Circular No. 106.

Hydrated lime should contain not more than 5 per cent. impurities, nor 3 per cent. carbon dioxide. It should be of such fineness that not more than ½ per cent. shall remain on a No. 30 sieve, nor more than 15 per cent. on a No. 200 sieve. It should pass the prescribed steaming test for soundness.

CAUSES AND PREVENTION OF THE FORMATION OF NON-CONDENSIBLE GASES IN AMMONIA ABSORPTION REFRIGERATION MACHINES.[10]

By E. C. McKelvey and Aaron Isaacs.

[ABSTRACT.]

IN the experiments conducted at the Bureau of Standards the conditions existing during the operation of an ammonia absorption refrigeration machine were duplicated. It was found that the presence of the non-condensible gases that cause so much trouble in the operation of these plants is due to either or both of these causes: namely, (1) leaks of air into the system, and (2) the corrosive action of the aqua ammonia on the metal of the plant.

If the "foul" gas is mainly nitrogen, the gas is derived from air that is leaking into the system. The oxygen originally present in the air is quickly used up when the plant is operating and so will be present in only a very small percentage of its original amount. If the foul gas is hydrogen, the cause is corrosion by the ammoniacal liquor. Pure aqua ammonia will not cause gas formation; but if salts of such weak acids as acetic or carbonic acid are present in the "aqua," the corrosive action will continue during the life of the charge. If the gas contains both nitrogen and hydrogen, both causes are present.

The corrosive action of impure aqua may be completely stopped by the addition of either sodium or potassium dichromate to the aqua in the plant. The dichromate is conveniently added in the form of a concentrated solution, and gas formation will be stopped if the salt is added to the extent of 0.2 per cent. of the weight of the aqua present. It is best to add the dichromate to the charge in all plants, as its presence decreases the very small amount of gas caused by even the highest grade ammonias.

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[10] Technologic Paper No. 180.

Gum Arabic.—The preparation and properties of gum arabic are described by J. A. RIDGWAY in the *Canadian Chemical Journal*, 1920, iv, 330–335. The gum is obtained from certain species of the genus *Acacia*. The trees may be tapped when three years old, and are most productive between seven and fifteen years of age. In tapping a tree, strips of its outer bark are removed, each strip is approximately two to three feet long by one to three inches broad. The gum slowly exudes as a liquid, which gradually hardens, and at the same time loses moisture. The tapping is made during the dry season, and the gum is removed from the tree from six to eight times during the season. The same tree is not tapped two years in succession, as a rule. If the gum contains more than 20 per cent. of water, it is tough and difficult to grind; if it contains less than 12 per cent. of water, it is too friable, and crushes during transportation. The gum is soluble in cold water, but usually contains 1 to 2 per cent. of impurities which are insoluble in that solvent. The solution is optically active and usually rotates the plane of polarized light to the left. Chemically, the gum is the metallic salt of a complex organic acid. The bases form 3 per cent. of the gum, and are the oxides of calcium, magnesium, and potassium. The complex organic acid, with which these bases are combined, may be split into simpler organic compounds; one of its molecules yields one molecule of arabic acid, two molecules of arabinose, and four molecules of galactose. The value of a given sample of the gum in the arts depends largely on the viscosity of its solution in water. Most of the gum imported into Canada is known as "Natural" and contains fragments of bark. The grade usually imported into the United States is termed "cleaned" and is free from bark and straw. Other grades are "cleaned and sifted," from which dust and sand as well as bark and straw have been removed, and "bleached," which has been rendered almost pure white by prolonged exposure to the rays of the sun.

J. S. H.

Lobinol—the Poison of Poison Oak.—JAMES B. MCNAIR (*Journal of the American Chemical Society*, 1921, xliii, 159–164) has extracted a dermatitant, or poison, producing inflammation of the skin, from the poison oak *Rhus diversiloba*. The bark was extracted with alcohol; and the extracted poison was purified by successive treatments with petroleum, ether, alcohol, sodium chloride brine, and distilled water. The poison apparently is an unsaturated compound of the aromatic series, containing carbon, hydrogen, and oxygen; it reacts like a phenol, and may contain two hydroxyl groups in the ortho position. On account of its phenolic nature, it has been named lobinol.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

A COLORIMETER OPERATING ON THE SUBTRACTIVE PRINCIPLE.[1]

By L. A. Jones.

[ABSTRACT.]

In this article a new type of colorimeter operating on the subtractive principle of color mixture is described. By means of a telescopic element an image of the object whose color is to be measured is formed in the plane of the photometric cube of the instrument. In this way one-half of the photometric field is illuminated by light of the color that is to be analyzed. The other part of the photometric field is filled with light the color of which can be varied so as to match that of the unknown. As a source of this light a small incandescent automobile headlight lamp is used, operated at constant voltage, and screened with a filter of such quality that the transmitted light matches noon sunlight in color, noon sunlight being defined as standard white. Between this lamp and the photometric cube are placed four gelatine wedges, three of which are colored, and one of neutral tint, the neutral tint wedge being used for adjusting the intensity factor in the comparison field. The three colored wedges used are the attractive primaries, namely, minus green, or magenta; minus blue, or yellow; and minus red or blue-green, these colors being complementary to the three-color additive primaries. Any unknown color can be matched by using two of the colored wedges in conjunction with the neutral tint wedge, and a complete specification of color is therefore obtained by giving the scale readings of the three wedges used. In this way a numerical specification of color in terms of the constants of the instrument can be obtained. Such a determination is not a true specification of color as such, but by means of suitable calibration tables these readings can be

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* Communicated by the Director.

[1] *Jour. Opt. Soc. Amer.*, November, 1920, p. 420. Communication No. 105, from the Research Laboratory of the Eastman Kodak Company.

converted into the absolute specification of color in terms of hue, saturation, and an intensity factor.

For convenience in measuring the color of various materials, special attachments are provided with another standardized lamp for illumination of the samples. As a standard of white against which the working lamps may be checked from time to time, a standardized lamp with an adjusted filter is provided in a suitable housing which may be attached to the instrument. By means of this the proper operating current for the working lamps may be determined at any time. The monochromatic analyses of the three colored wedges used in the instrument are given in graphic form in the paper.

PHOTOGRAPHIC SHARPNESS AND RESOLVING POWER.[2]

By F. E. Ross.

THE paper begins with a summary of the more important relations between the fundamental photographic variables. It is shown how to calculate the sharpness of any image solely from the gamma of the emulsion and from the rate of growth of the image with exposure. The important practical case of variation of sharpness with the color of the light is thoroughly discussed. While actual measurements of the variation of sharpness with wave-length and with time of development prove the theoretical equation derived, to be but a first approximation; the equation indicates that to secure sharp images emulsions with both high contrast and low turbidity should be selected, also those whose characteristic curves have a small "toe." Various secondary factors which affect sharpness are discussed. Tugman's method of measurement was improved and extended to densities of about 3. A theoretical formula is derived to show the variation of the resolving power of a photographic plate with the sharpness and the grain size. As an illustration, physical development of a Seed 23 plates gives images with one-fifth the sharpness obtained by chemical development, yet the grains were so much smaller that the resolving power was 20 per cent. more. The theory also explains observed variations with time of development and with wave-length, the effect of intensification, etc. By taking pains to secure fine grains, the resolving power of a wet collodion plate may be made almost equal to the theoretical maximum for the lens used. It is suggested that astronomers are inclined to overestimate the advantage of small grain-size; for the true resolving power of some coarse-grained emulsions is far ahead of that obtainable with large telescopes. As a rule, what is needed is rather higher speed than better resolving power.

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[2] *Astrophys. J.*, November, 1920. p. 201. Communication No. 90, from the Research Laboratory of the Eastman Kodak Company.

Preliminary Results of Ocean Magnetic Observations on the Carnegie from St. Helena to Cape Town and Thence to Colombo, Ceylon, April to June, 1920. J. P. AULT, Commander. (*Terrestrial Magnetism and Atmospheric Electricity*, September, 1920.)—The *Carnegie* continues to put a good, substantial, magnetic girdle round the earth in this voyage of 6665 nautical miles of forty-one days' length. Declination observations were made twice daily, while the determination of inclination and of horizontal intensity was made only once per day. The differences between the observed values and the corresponding quantities recorded in U. S. Hydrographic Office Charts for 1920, in British Admiralty Charts for 1907, and with the Reichs-Marine-Amt Charts for 1910 and 1905 are tabulated. The departure of the German charts from the fact is especially noticeable in the case of the inclination. At one place not far from St. Helena it amounted to more than ten degrees, while the maximum difference for the British chart was 5.1° and for the American 3.3°, these two maxima occurring at the same spot about thirteen days before Colombo was reached. In declination the largest error of the British chart seems to be 2.3°, of the German 5.6°, and of the American 3.3°.

There is a hint of trouble with the crew at Cape Town, where the local authorities "gave the *Carnegie* every consideration in the way of free dockage, free pilotage and free towboat service, a courtesy very much appreciated."

G. F. S.

Absorbent Cotton.—Purified or absorbent cotton is almost pure cellulose. Standard requirements for absorbent cotton are suggested by A. WAYNE CLARK, R. O. SMITH, and LEROY FORMAN (*Journal of the American Pharmaceutical Association*, 1920, ix, 958–965). It should be free from acids, alkalies, and dyes, should contain not more than 0.2 per cent. of ash, not more than 0.25 per cent. of water-soluble solids, and not more than 0.6 per cent. of fatty matter, and should become wet and sink immediately if compressed in the hand, then thrown on the surface of water which has a temperature of 25° C.

J. S. H.

The Use of Wood as Fuel in Industry. (*Le Genie Civil*, December 11, 1920.)—In March, 1920, the French minister of Public Works appointed a commission to study the utilization of fuel to the best advantage—a pressing necessity in a country whose coal mines had been so largely rendered unproductve by the German invaders. This wide field was divided among three sub-committees to which were allotted respectively the following subjects of consideration: The reduction of the use of coal by steam engines; the economizing of fuel in metallurgy and in industries on a large scale; and last, inventions and special processes (pulverization and gasefication of coal, etc.). The Ministry of Public Works is to publish from time to time the important findings of the commission. Thus from the second of the above named subcommittees comes the report on wood, prepared by M. Cornu-Thenard.

It is, to say the least, difficult to get sufficient supplies of fuel from countries outside of France and all such importation helps to make the balance of trade against that country still worse.

It is, therefore, wise to try to use the available wood found in the country and its colonies. There are in France about 10,000,000 hectares of forest (1 hectare equals 2.47 acres), and the colonies possess ten times as great an area of woodland. Before the war France produced annually 35,000,000 steres (1 stere equals 35.3 cu. ft.; 3.6 steres equal 1 cord) of firewood. Not so much can now be got from the forests, but this loss would be about made up if the wood derived from hedges and from trees along canals and roads be counted in. Owing to the high cost of fuel the wood crop is better looked after than formerly. From 3 to 5 steres of wood will give as many calories as a ton of coal, and the wood is cheaper than the equivalent coal in the locality where it is cut.

The heating power of wood is a function of its moisture content and methods of drying it are discussed. The ashes of a ton of wood give more than 7 pounds of alkaline carbonate, available for fertilizer. There are numerous drawbacks to the employment of wood, such as greater cost of handling, greater storage space needed, greater fire risk, and higher relative cost of shipment. For these reasons it is chiefly in well-wooded regions alone that wood can be expected to replace coal. It is not, therefore, surprising to read that in Alsace wood is used to fire boilers and that in Franche-Comté it has been used in the Martin steel works. The Commission recommends that managers of industrial plants consider carefully the claims of wood and, further, that in the rationing of fuel to the various parts of France the supply of available wood be considered.

G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CANTALOUPE SEED OIL.[1]

By Walter F. Baughman, Dirk Brauns, and George S. Jamieson.

[ABSTRACT.]

An oil obtained by means of the oil expeller from a large sample of cantaloupe seed (*Cucumus melo*), from Imperial Valley, Calif., was investigated. The cold-pressed oil has a pale yellow color and a pleasant fruity taste. Although the oil had stood at room temperature for two years, it had no trace of rancid odor or taste.

The chemical and physical characteristics were found to be as follows:

Specific gravity, at 25°/25° C.	0.9210
Refractive index at 20° C.	1.4725
Iodine number (Hanus)	125.9
Saponification value	192.3
Reichert-Meissl number	0.33
Polenski number	0.26
Acetyl value	15.8
Acid value	.43
Unsaponifiable matter (per cent.)	1.1
Soluble acids (per cent.)	0.4
Insoluble acids (per cent.)	94.
Saturated acids (per cent.)	14.3
Unsaturated acids (per cent.)	80.2

The chemical composition of the oil was found to be as follows:

Glycerides of:	
Myristic acid	0.3
Palmitic acid	10.2
Stearic acid	4.5
Oleic acid	27.2
Linoleic acid	56.6
Unsaponifiable matter	1.1

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* Communicated by the Chief of the Bureau.

[1] Published in *J. Am. Chem. Soc.*, 11 (1920), 2398.

SUGAR-CANE JUICE CLARIFICATION FOR SYRUP MANUFACTURE.[2]

By J. K. Dale and C. S. Hudson.

[ABSTRACT.]

AN investigation of methods now used for manufacturing cane syrup showed that it is possible to produce a superior article by clarification of the sugar-cane juice with infusorial earth. This method of clarification is feasible in any factory using steam as the source of power and results in an excellent quality of syrup. Such syrup has a milder flavor than the present Louisiana type and is lighter in color and cleaner than the Georgia type of syrup.

HYDROLYSIS OF THE GLOBULIN OF THE COCOANUT, COCOS NUCIFERA.[3]

By D. Breese Jones and Carl O. Johns.

[ABSTRACT.]

THE total globulin of the cocoanut was hydrolyzed by boiling with 20 per cent. hydrochloric acid for 36 hours and the resulting amino-acids have been determined.

By changing the order of procedure usually followed in connection with protein hydrolysis, and by applying several rather recently described methods, 78.15 per cent. of the hydrolysis products of the protein used has been identified and determined.

The order of procedure followed in the isolation and determination of the animo-acids was as follows: Removal of the hexone bases with phosphotungstic acid; separation of most of the glutaminic acid as the hydrochloride; precipitation of the remaining di-basic amino-acids as their calcium salts; extraction of proline and peptide anhydrides with absolute alcohol; esterification of the remaining amino-acids by means of the lead salt method of Foreman; fractional distillation of the esters under reduced pressure; and, finally, regeneration and isolation of the amino-acids in the usual manner.

The following percentages of amino-acids were found: Glycine, trace; alanine, 4.11; valine, 3.57; leucine, 5.96; proline, 5.54; phenylalanine, 2.05; aspartic acid, 5.12; glutaminic acid, 19.07; hydroxyglutaminic acid, 0.00; serine, 1.76; tyrosine, 3.18; cystine, 1.44; arginine, 15.92; histidine, 2.42; lysine, 5.80; tryptophane, present; leucylvaline anhydride, 0.64; ammonia, 1.57.

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[2] *U. S. Dept. Agr. Bull., 921,* issued Nov. 9, 1920.

[3] Published in *J. Biol. Chem.,* 44 (1920), 291.

NOTES FROM THE U. S. BUREAU OF MINES.*

TREATING NATURAL-GAS GASOLINE TO MEET THE "DOCTOR TEST."

By D. B. Dow.

The problem of making natural-gas gasoline that will pass the test for objectionable sulphur compounds, known as the "doctor test," has been in the past a matter of no importance to the manufacturers of casing-head or absorption gasoline, because their market was limited to refineries, which mixed the product with "straight-run" gasoline and purchased it on a gravity or distillation basis. Recently an export market has opened for this type of gasoline, so it is now desirable that it pass the "doctor test."

The Bureau of Mines has worked out, at its petroleum station at Bartlesville, Okla., a cheap and efficient method for treating the gasoline to render it "sweet" to the doctor test. The method is, briefly, scrubbing the gasoline with a solution consisting of 20 per cent. caustic soda, 7 per cent. litharge, with 2 or 3 per cent. powdered sulphur added, then rewashing with water. The method of application will vary in different plants, as a wide variety of scrubbing installations could be used. One simple arrangement is to introduce the gasoline at the bottom of a steel tower packed with steel shavings, and filled three-quarters full of the solution, the gasoline being drawn off at the top into a second tower containing water and steel shavings.

A fuller account is given in a recent report issued by the bureau.

CONSUMPTION OF REAGENTS USED IN FLOTATION.

By Thomas Varley.

In April, 1919, the Bureau of Mines requested mill operators to supply information on the tonnages treated both by gravity concentration and flotation, the amount of concentrates produced by each system of milling, and the consumption of oils, acids, and other reagents used, for the year 1919. Some delay was experienced in collecting the data, but eventually returns were obtained from practically all the important plants.

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* Communicated by the Director.

The results have been recently published in tabular form by the bureau. The amount of ores of all kinds treated by flotation was 26,545,564 tons, from which 3,105,343 tons of concentrates were obtained, showing a concentration ratio of 8.55 tons into one. The total of all reagents used was 113,510,234 pounds, equivalent to 4.2384 pounds per ton of ore treated. The bulk of the ores treated was copper ore, the rest being lead and lead-silver ores, zinc ore, gold-silver ore, graphite ore, and miscellaneous ores, such as molybdenum and antimony, and complex mixed ores of various kinds.

The most generally used flotative agents for copper ores are sulphuric acid, kerosene acid sludge, and coal tars. For lead and silver ores, hardwood creosote is used most, followed by coal tar, crude petroleum, and pine oils. For zinc ores, pine oil is the most important, with copper sulphate second, and creosote third.

Miscellaneous agents used are sulphur, specially prepared fractions of coal creosote, wood creosote, and pine oil, also various sodium salts, ammonia, ammonium salts, etc.

TESTS OF MINERS' FLAME SAFETY LAMPS IN GASEOUS, COAL-DUST LADEN ATMOSPHERES.

By L. C. Ilsley.

Several writers have called attention to the possible failure of flame safety lamps in coal-dust laden air, and question the safety of a lamp tested in gas alone. Some attention has been given this question, but the practice has generally been to test lamps in gas and air mixtures only.

Before revising its official schedule for the testing of flame safety lamps, the Bureau of Mines recently conducted a series of tests with coal dust present, which indicated that under certain conditions, coal dust might have some slight effect. Partly as a result of these experiments, and partly because it would more nearly represent actual conditions in a coal mine, the bureau has decided that in its revised schedule for approval of flame lamps, a certain proportion of the tests in explosive mixtures of gas and air will be made with coal dust present. Details of the experiments are given in a recent report issued by the bureau.

MINOR NOTES.

Volatilization Tests on a Low-grade Ore.—The Intermountain experiment station of the Bureau of Mines, at Salt Lake City, which is making an extensive study of the metallurgy of the volatilization process, recently completed a series of experiments on a low-grade oxidized ore from Nevada, assaying 0.286 ounce gold, 3.4 ounces silver, and 4.5 per cent. lead. The experiments showed that 80 per cent. of the gold, 75 per cent. of the silver, and 76 per cent. of the lead could be volatilized with the addition of sodium chloride alone. The use of a small amount of calcium chloride in addition to the sodium chloride, increased these recoveries by about 10 per cent.

Uranium Ore Deposit.—It is reported that a mining company has opened and is developing a uranium property near Lusk, Wyoming. The ore is an unusual oxide of uranium, and determinations made by the U. S. Bureau of Mines experiment station at Golden, Colo., indicate that the deposit is likely to prove of importance.

Devitrification of Glass.—The devitrification, which occurs when glass is heated for working in the flame, is a surface phenomenon and is due to the separation of silica. ALBERT F. O. GERMANN, of Western Reserve University, who has studied this phenomenon, has found that devitrification is prevented if the glass be washed in dilute hydrofluoric acid prior to working in the flame. This washing removes the "weathered" surface of the glass, and thereby prevents the separation of silica. (*Journal of the American Chemical Society,* 1921, xliii, 11–14.)

J. S. H.

New Type of Organic Compound of Arsenic.—GEORGE JOSEPH BURROWS and EUSTACE EBENEZER TURNER, of the University of Sydney (*Journal of the Chemical Society,* 1920, xcvii, 1373–1383), have discovered a new group of organic compounds of arsenic. Many organic arsines in which the three hydrogen atoms of arsine, AsH_3, have been replaced by similar or dissimilar alkyl or aryl groups, readily combine with methyl-diiodo-arsine and with the corresponding ethyl and phenyl compounds to form new compounds which vary in color from pale yellow to deep orange. Each of these new additive compounds contains two atoms of arsenic in its molecule. Thus phenyl-ethyl-methyl-arsine reacts with methyl-diiodo-arsine to form the addition compound $C_6H_5.C_2H_5.CH_3As.CH_3AsI_2$. The structural formulæ of the new compounds are uncertain.

J. S. H.

Construction of a Plant for the Utilization of the Tidal Energy. (*La Nature,* October 30, 1920.)—To help to replace the loss of energy inflicted upon France by the destruction of her coal mines by the Germans there will be built at La Landriais, five miles from St. Malo in the northwest of France, a plant in which turbines will be driven by tidal water. Here on both sides of the Rance River there are natural basins which are covered by each tide. These have an area of 20,000 hectares and the tides are very high. Four dams will be built. The cycle of operations will, of course, repeat itself every twelve hours and twenty-four minutes, the tidal interval.

Two reservoirs are required, one at high level to be filled at high tide, and the other at low level to receive water from the first and to empty it into the sea at low tide. The cycle is that of Decoeur, presented to the Academy of Sciences in 1891. Let us suppose that it is low water at 1:30. The gates of the low reservoir are closed and it is shut off from the sea, but the level of the water in it rises continuously on account of the arrival of water from the higher reservoir, which passes through the turbines on its way down. At 1:30 the upper reservoir is likewise isolated from the sea. Its level falls as its water runs into the lower basin, while the level of the sea rises with the rising tide. These two levels become the same at 4 o'clock. Then the gates are opened and the high reservoir is filled up as the tide comes in. Meanwhile the turbines are kept in operation by water running through them to the basin below. At 7 o'clock, the end of dead water, the gates of the upper reservoir are closed. The water within continues to flow into the lower reservoir. At 11 o'clock the level of the water in the sea will have sunk to that of the lower basin, which has been rising ever since 1:30. The gates of the latter are opened and its water flows into the sea as its level falls. At 2 o'clock the gates of the lower basin will be again closed as they were at 1:30, twelve and a half hours before, and the same series of operations will be repeated. At neap tide 5000 horsepower will be developed, and at spring tide ten times as much. An annual output of more than 150,000,000 kilowatt hours is expected.

The practical operation of this plant will be scanned with great care, all the more because it is just here in the northwest of France that there is no stream power to be developed.

G. F. S.

America's Share of the World's Gold. (*Eng. and Mining Jl.,* December 11, 1920, p. 1129.)—Of a total accumulation through the ages of $8,000,000,000 in monetary gold, the United States is estimated to hold $2,500,000,000, or 30 per cent., of the world's supply. Gold holdings were increased greatly during the war because of the heavy shipments of gold made by other nations to the United States in payment for commodities.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 19, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 19, 1921.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 13.

A report of Progress was presented by the Committee on Library.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-President, Treasurer and members of the Board of Managers, and the followng gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Charles Day, Vice-President (to serve three years).

Benjamin Franklin, Treasurer (to serve one year).

Charles E. Bonine, Alfred W. Gibbs, Howard S. Graham, George R. Henderson, George A. Hoadley, Lawrence T. Paul, James S. Rogers and C. C. Tutwiler, Managers (to serve three years).

The President extended the thanks of the meeting to the tellers for their services.

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1920, with the reports of the various standing committees of the Institute and the Board of Managers.

Mr. John W. Lieb, M.E., Vice-President, the New York Edison Company, was then introduced and read the paper of the evening entitled, "Leonardo da Vinci—Philosopher and Engineer." A review was presented of the activities of Leonardo da Vinci as a philosopher and engineer, with an account of his work in military, civil, mechanical and hydraulic engineering, aviation, geology, anatomy, optics and many other branches of science, literature and the arts. The lecturer pointed out that Leonardo was one of the greatest intellects of all time, assigning to him an even higher place in philosophy, science and mechanics than he already holds in the history of the graphic arts. The subject was illustrated by lantern photographs from his note-book.

A rising vote of thanks was extended to the speaker, and the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 5, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 5, 1921.

MR. CHARLES PENROSE *in the Chair.*

The following reports were presented for final action:

No. 2744: Republic Flow Meter. The Edward Longstreth Medal of Merit to Mr. Jacob M. Spitzglass, of Chicago, Illinois.

No. 2764: Use of the A. C. Electro-Magnet in Surgery. The Edward Longstreth Medal of Merit to Professor J. Bergonie, of Bordeaux, France.

No. 2765 and No. 2766 } The Franklin Medal. The Franklin Medal to Professor Charles Fabry, of the University of Marseilles, France, and Mr. Frank J. Sprague, of New York, N. Y.

The following report was presented for first reading:

No. 2761: Greaves-Etchells Electric Arc Furnace.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 6, 1921, at 8 o'clock. Dr. Harry F. Keller in the Chair. The minutes of the previous meeting were approved as read.

L. I. Shaw, Ph.D., Assistant Chief Chemist of the U. S. Bureau of Mines, and formerly Captain, Chemical Warfare Service, in charge of Smoke and Incendiary Section, C.W.S., A.E.F., delivered a lecture on "Smoke and Incendiary Materiél." An account was given of the development, uses, mode of employment, and relative merits of the portable and non-portable flame projectors, smoke producers, smoke bombs, incendiary bombs and other smoke and incendiary materials used by the various belligerent nations. The lecture was illustrated with lantern slides and specimens.

After a lengthy discussion of his communication, a vote of thanks was tendered Dr. Shaw, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, January 13, 1921, in the Hall of the Institute. Mr. Coleman Sellers, Jr., in the Chair.

The paper of the evening on "The Modern Cargo Vessel" was presented by Mr. William Gatewood, of the Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia. An outline was given of the history and development of cargo vessels and their importance in world economics. The present types were discussed as well as the effect of their material, size, speed, construction and equipment on their usefulness. Some of the problems involved in their building and operation were discussed and the importance of proper governmental action if the home port of the vessel carrying our cargo is to be in this country instead of abroad, as it was before the war. The subject was illustrated by lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 12, 1921.)

RESIDENT.

MISS CAROLINE D. BLACKBURN, 207 South Third Street, Philadelphia, Pennsylvania.

MR. WALTER J. COPPOCK, Box 2, Logan Hall, University of Pennsylvania, Philadelphia, Pennsylvania.

MR. J. W. VAN DYKE, The Wellington, Philadelphia, Pennsylvania.

MR. FRANK H. ROGERS, William Cramp & Sons Ship & Engine Building Company, Philadelphia, Pennsylvania.

NON-RESIDENT.

DR. JOSEPH S. AMES, The Johns Hopkins University, Baltimore, Maryland.

DR. ARTHUR L. DAY, Carnegie Institution, Washington, D. C.

DR. HENRY PHELPS GAGE, Corning Glass Works, Corning, New York.

DR. M. LUCKIESH, Nela Park, Cleveland, Ohio.

DR. P. G. NUTTING, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

DR. M. POSER, 16 Vick Park B, Rochester, New York.

DR. CHARLES SHEARD, Southbridge, Massachusetts.

PROF. JAMES P. C. SOUTHALL, Columbia University, New York City, New York.

ASSOCIATE.

MR. DANIEL BACHE, 2102 Pine Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. CHARLES G. ADSIT, 555 Electric & Gas Building, Atlanta, Georgia.

MR. WALTER ATLEE, Box 173, Beckley, West Virginia.

MR. M. C. BURT, 636 Water Street, Bridgeport, Connecticut.

MR. HALCOLM ELLIS, Fabrique Nationale d'Armes de Guerre, Herstal-les Liege, Belgium.

MR. F. J. GUBELMAN, Woodland Avenue, Englewood, N. J.

MR. JOHN D. MCILHENNY, 17th and Clearfield Streets, Philadelphia, Pennsylvania.

MR. J. B. PORTER, 1527 Spruce Street, Philadelphia, Pennsylvania.

MR. J. R. WATKINS, Apartment 6 Belmont, College Hill, Cincinnati, Ohio.

LIBRARY NOTES.

PURCHASES.

CAIN, J. C.—The Chemistry and Technology of the Diazo-Compounds. 1920.
CARMICHAEL, R. D.—The Theory of Relativity. 1920.
CLAYTON, W.—Margarine. 1920.
CREHORE, A. C.—The Atom. 1920.
EINSTEIN, A.—Relativity. 1920.
HERSHEY, H. E.—Automatic Telephone Practice. No date.
KNOWLES, M.—Industrial Housing. 1920.
KNOWLES, M.—Machinery's Encyclopædia. 7 vols. 1917.
MALATESTA, G.—Coal Tars and Their Derivatives. 1920.
NOYES, A. A.—A Course of Instruction in the Qualitative Chemical Analysis. 1920.

GIFTS.

Cooling Tower Company, Inc., Catalogue No. 9A. New York City, New York, 1920. (From the Company.)
Crouse-Hinds Company, Bulletin 1000M. Syracuse, New York, 1920. (From the Company.)
Dart, E. M., Manufacturing Company, Catalogue, Dart Union Fittings. Providence, Rhode Island, 1920. (From the Company.)
Engineer Company, Modern Practice in Combustion Control. New York City, New York, 1920. (From the Company.)
Flexible Steel Lacing Company, Short Cuts to Power Transmission. Chicago, Illinois, 1920. (From the Company.)
Franklin Railway Supply Company, Incorporated, Bulletin No. 601. New York City, New York, 1920. (From the Company.)
General Planters Supply Company, Inc., Electro-Plating and Polishing Materials. New York City, New York, 1920. (From the Company.)
George Washington University, Catalogue 1920. Washington, D. C., 1920. (From the University.)
Great Britain Meteorological Committee, Fifteenth Annual Report. London, England, 1920. (From the Committee.)
Institute of Automobile Engineers, Proceedings, Vol. 14. London, England, 1920. (From the Institute.)
Keasbey and Mattison Company, Booklet on Power and Heating Systems, Ambler, Pennsylvania, 1920. (From the Company.)
Kelly Controller Company, The Kelly Low and High Pressure Controller. Chicago, Illinois, 1920. (From the Company.)
Kennedy-Van Saun Manufacturing and Engineering Corporation, Kennedy Gearless Crusher, Bulletin No. 2. New York City, New York, 1920. (From the Corporation.)
LaMotte Chemical Products Company, Booklet on Soil Acidity and a Field Method for its Measurement. Baltimore, Maryland, 1920. (From the Company.)
Link-Belt Company, Catalogue No. 440. Chicago, Illinois, 1920. (From the Company.)

Locomotive Stoker Company, Type "D" Duplex Locomotive Stoker. New York City, New York, 1920. (From the Company.)

Magnesia Association of America, Defend your Steam. Philadelphia, Pennsylvania, 1920. (From the Association.)

Merchants Association of New York, Year Book, 1920. New York City, New York, 1920. (From the Association.)

Merrill Company, Booklet on the Merco Nordstrom Plug Valve. San Francisco, California, 1920. (From the Company.)

Mine and Smelter Supply Company, Bulletin No. 63. New York City, New York, 1920. (From the Company.)

Mitchell-Tappen Company, Bulletin 14. New York City, New York, 1920. (From the Company.)

Mound Tool Company, General Tool Catalogue No. 7. St. Louis, Missouri, 1920. (From the Company.)

National Carbon Company, Inc., Catalogue No. 35 and The Carbon Electrode. New York City, New York, 1920. (From the Company.)

National Fire Protection Association, Year Book and Index. Boston, Massachusetts, 1920. (From the Association.)

National Physical Laboratory, Report for the Year 1919. London, England, 1920. (From the Laboratory.)

New Zealand Institute, Transactions and Proceedings, Vol. lii. Wellington. (From the Institute.)

Ontario Department of Mines, Twenty-ninth Annual Report. Toronto, Canada, 1920. (From the Department of Mines.)

Pawling and Harnischfeger Company, Hand-Book of Electric Traveling Cranes and Hoists. Milwaukee, Wisconsin, 1920. (From the Company.)

Powers-Weightman-Rosengarten Company, P-W-R Manual. Philadelphia, Pennsylvania, 1920. (From the Company.)

Quigley Furnace Specialties Company, Hytempite in the Gas Plant. New York, New York, 1920. (From the Company.)

Roebling's Sons Company, Booklets on Wire and Rope Fittings. Philadelphia, Pennsylvania, 1920. (From the Company.)

South Bend Lathe Works, Red Book No. 61. South Bend, Indiana, 1920. (From the Works.)

Standard Underground Cable Company, Bulletin No. 740-1. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Stuebner, G. L., Iron Works, Catalogue No. 75. New York City, New York, 1920. (From the Works.)

Sullivan Machinery Company, Bulletins, Nos. 70-J, 71-D, and Booklet No. 122. Chicago, Illinois, 1920. (From the Company.)

Technical Supply Company, General Catalogue, Ninth Edition. Scranton, Pennsylvania, 1920. (From the Company.)

Thompson, W. P., and Company, Handbook of Patent Law of all Countries. London, 1920. (From the Company.)

Traylor Engineering and Manufacturing Company, Bulletin No. 101. Allentown, Pennsylvania, 1920. (From the Company.)

United States Brewers' Association, 1919 Year Book. New York City, New York, 1920. (From the Association.)

Vanadium-Alloys Steel Company, Pamphlets on Tool Steel. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Warren Webster and Company, Bulletin No. 301. Camden, New Jersey, 1920. (From the Company.)

Western Reserve University, Report of the President, 1919-1920. Cleveland, Ohio, 1920. (From the University.)

Wheel Trueing Tool Company, Catalogue of Diamonds and Diamond Pointed Tools. Detroit, Michigan, 1920. (From the Company.)

Whitman and Barnes Manufacturing Company, Catalogue No. 92. Akron, Ohio, 1920. (From the Company.)

Whiting Foundry Equipment Company, Booklet No. 153. Harvey, Illinois, 1920. (From the Company.)

Wing Manufacturing Company, Bulletin No. 58 A. New York City, New York, 1920. (From the Company.)

Winter Brothers Company, Catalogue No. 14. Wrentham, Massachusetts, 1920. (From the Company.)

Yale University, Report of the President, 1920. New Haven, Connecticut, 1920. (From the University.)

BOOK NOTICES.

DAS KUGELPHOTOMETER. (ULBRICHT'SCHE KUGEL.) von Dr. Ing E. h. Dr. Richard Ulbricht. 110 pages, 31 illustrations, 3 tables and contents. Berlin, R. Oldenbourg, 1920. Price, 24 marks in paper, 28 marks bound.

The literature on the subject of the Ulbricht sphere, as used in photometry, is so scattered that a comprehensive discussion by the original inventor should be very welcome, particularly at this time when the sphere has found such extensive application in commercial as well as standard practice. While various forms of integrating photometers have been invented and described, prior to the last few years, their use in practice was almost entirely confined to the measurement of arc lamps or lamps and reflectors. But the impracticability of rotating the gas-filled tungsten incandescent lamps brought them into the same class as the arc lamps, and so greatly increased the demand for an instrument measuring total flux. The simplicity of the so-called "sphere" photometer has led to its adoption by lamp factories as well as standardizing laboratories.

The book is divided into ten chapters, the first of which is devoted to a brief historical survey. Credit is given to Dr. W. E. Sumpner, who described the principle of the sphere as early as 1892–3, but without referring to its use in photometric practice. The author was led to an independent discovery through a study of the laws of light distribution in interiors. The second chapter discusses the fundamental theory on which is based the application of the sphere to the measurement of total flux and mean spherical candlepower. The next chapter describes the early investigations in which the effect of extreme differences in the light distribution of the source, the position of the source in the sphere, and the effect of a translucent instead of an opaque shielding screen are tested.

The theory of the sphere assumes a source of light without any obstructing parts which would absorb or otherwise influence the free reflection of light from and to all points on the inner surface of the sphere. As it is obviously impossible to attain this condition in an actual instrument, it becomes necessary to determine the effect of the presence of "foreign" bodies, such as the shielding screen, the lamp holder and, when used, other screens and a second lamp. A chapter is devoted to this broad subject and another chapter to the shielding screen, whose size, position and character, translucent or opaque, are very important factors in the relation of the illumination of the sphere window to the total flux. The window itself is discussed in a separate chapter.

The general theory also assumes an interior surface which is perfectly diffusing, *i.e.*, obeys Lambert's cosine law, and as such a surface is not obtainable in practice, the effect of departure from the law, due to the paint used to coat the surface, must be ascertained. In this connection the author refers freely to the work of E. Dyhr, who in 1910 made a somewhat extended investigation both of the effect of departure from Lambert's law, and of lack of whiteness in the paint. For those who wish to make a sphere or wish to repaint one, a recipe is given for a paint adopted by the Lichtkommission des Verbandes Deutscher Elektrotechniker.

The remaining chapters are devoted to special uses of the sphere, such as the measurement of mean hemispherical candlepower, to methods of measurement, and finally to the construction of the sphere, the materials used, ventilation, size, arrangement of equipment, and special devices, such as the compensating screen of Benford.

While not much has been published in this country on the subject of the integrating sphere, it seems somewhat regrettable that in a book devoted to the subject no reference is made to the analytical and experimental work of Chaney and Clark and to that of Rosa and Taylor at the Bureau of Standards, both presented before the U. S. Illuminating Engineering Society. The book could be made more complete in subsequent editions by the inclusion of a description of work done in England on the so-called "Box Integrator," which is a modification of the idea of the sphere. It may be added for the benefit and encouragement of the reader who is not an adept in the German language that the diction is not difficult.

F. E. CADY.

THE HUMAN MOTOR OF THE SCIENTIFIC FOUNDATIONS OF LABOR AND INDUSTRY. By Jules Amar, D.Sc., Director of the Industrial Laboratory at the Conservatoire National des Arts et Métiers. Paris, 8vo., 466 pages, contents, index, 309 illustrations and numerous tables. New York, E. P. Dutton & Co. $10.00 net.

It is somewhat difficult to appraise this volume. Originally appearing in France, in 1914, the English translation had to be deferred on account of the war. The names of the translators, Elsie P. Butterworth and George F. Wright, appear only in small type on the verso of the title-page, without information as to their relation to the subject in hand. The purpose of the book is, as the author says in the preface, to bring together in one volume all the physical and physiological elements of industrial work. Taylor's system of efficiency is looked upon very favorably by the author, although it seems that in the United States its popularity has not been maintained at the original level.

Eighty-four pages are taken up with a discussion of general principles—statics and kinetics, dynamics and energetics, resistance of materials and elasticity. About eight pages are devoted to the structure and functions of the "Human Machine." Then follow sections on "Human Energy," "Man and His Environment," "Experimental Methods," and the closing section on "Industrial Labor." The extent of literature consulted is enormous, almost every page has several foot-note references, in which French, German and English authorities are mentioned. One notes with pleasure that American work is frequently quoted.

The book is essentially a treatment of the human being as a motor, and a discussion of the conditions under which the greatest efficiency can be obtained. As a general conclusion the human motor is stated to be probably an "electro-capillary" engine, in which nervous excitation modifies the superficial tension and produces contraction, but the nature of the nervous agent and the origin of human motive power are not yet known. The efficiency of the human motor is high, and the average duration of its activity is greater than that of any inanimate prime mover, the human motor being capable of self-repair. Brief stoppage of nutrition does not immediately suspend the action of the human machine, as does the stoppage of supplies to inanimate motors. Further, the human machine is capable of improvement, while the efficiency of an inanimate machine is best when new. As a criticism of Taylor's system, the author says that Taylor does not give sufficient weight to the physiologic factor. Naturally Doctor Amar is most interested in the improvement of efficiency of the French workman and soldier. An allusion to the defeat at Sedan is evidence that the present English text is derived from a work written before the late war.

The work contains a large amount of information, much of it in small details. It seems to have been well translated. Typographic errors are few, and not misleading, so far as the reviewer has noted.

HENRY LEFFMANN.

PRIESTLEY IN AMERICA. 1794–1804. By Edgar F. Smith, University of Pennsylvania. 12mo. 173 pages. Philadelphia, P. Blakiston's Son & Co. $2.00 net.

Doctor Smith has turned his attention for several years of late to the history of chemistry in America, and has brought into notice many highly interesting facts. Among these is that the first society, so far as records go, for the special study of chemistry was formed in Philadelphia. Every citizen of the United States knows that Philadelphia was for many years the leading city, both in population and importance, in this part of the world. It lost its place as the capital of the nation by reason of a "deal" between certain southern congressmen and their northern colleagues. The story can be found in the records.

The story of Priestley in America has many points of interest. He was not only an eminent chemist, but he took active part in certain religious movements of the time. In those days the minds of men and women seem to have taken religious dogmas more seriously, as a rule, than do the people at large to-day. Piety, deep and sincere, is still much in evidence, but familiarity with the general run of educated people, and especially scientists, shows a general indifference to the points of dogma which, after all, constitute the substance of a religious faith.

Priestley began his active career as a Presbyterian minister, but theologic ideas that are commonly called Unitarian seemed to develop early in his preaching. He acquired a knowledge of the semitic languages. He began, about 1760, to write tracts opposing the attitude of the British government towards the colonies. He took up a line of research on "different kinds of air" which was part of the general development of "pneumatic chemistry," that led to so much progress in the last half of the eighteenth century. His coming to America was largely due to his favorable attitude towards the French revolution, in its early stages, and when on July 14, 1791, a dinner was arranged in Birmingham to celebrate the fall of the Bastille, he was the object of mob violence although he said that he had little to do with the affair. The mob destroyed his house and chapel and many valuable records. He retreated to London, where though safe from attack, he was not well received by many scientists. He accepted a preaching position, which he filled until 1794, when he came to the United States, arriving at New York, but finally settling at Northumberland, Pa., where he lived until his death in 1804.

Doctor Smith has searched the contemporary newspapers, documents and books and has woven the data thus obtained into a most interesting narrative of the man, whom he calls correctly a "wonderful figure in science, history, religion, politics and philosophy." In these days, when it seems to be the custom, as stated above, of educated men to be non-committal on all topics but those of their specialty or business, it is refreshing to read in Doctor Smith's book that Franklin called Priestley an "honest Heretic," and then adds: "I think, all the heretics I have known were virtuous men." Doctor Smith's view is, by the way, that Franklin developed Priestley into a man of science.

The book is one to be read straight through, by which a vivid picture can be obtained of the personality and abilities of the great chemist in exile, and also, incidentally, a picture of the curious features of the phlogiston discussion.

HENRY LEFFMANN.

PAPERS ON PAINT AND VARNISH AND THE MATERIALS USED IN THEIR MANUFACTURE. By Henry A. Gardner, Director, Scientific Section, Paint and Varnish Manufacturers' Association of the United States. 501 pages, illustrations, 8vo. Washington, D. C. Published by the author, 1920. Price, $10.

This new volume of 500 pages, profusely illustrated, comprises the work done by Mr. Gardner, at the Institute of Industrial Research, for the Educational Bureau of the Paint Manufacturers' Association of the United States and the National Varnish Manufacturers' Association during the past two years, the result of work previously done having been embodied in two earlier volumes entitled, respectively, "Paint Technology and Tests" and "Paint Researches and Their Practical Application."

As Technical Director of the Educational Bureau, engaged continuously in research on the technology of the paint and varnish industry for the past ten or twelve years, he has had an unparalleled opportunity to familiarize himself with the subject, and has naturally become perhaps our foremost authority thereon.

The results of his researches and other work issued in the form of technical circulars and bulletins to the members of the two Associations, and later, at regular intervals, are collected and edited by Mr. Gardner and issued in permanent form. The present volume is the third of the series. It covers a wide range of subjects, all directly connected with paint or varnish technology, and many of the papers included have been adopted as regular working standards in the industry. This is especially true of the chapter entitled "Bulking Values and Yields of Pigments and Liquids Used in Paint and Enamel Manufacture," involving, as it did, over six months of work in his own laboratory and the laboratories of the Bureau of Standards. The same may be said of the "Standard Specifications of the War Department" and the "Interdepartmental Specifications" of the U. S. Government, in the preparation of which Mr. Gardner played an important part.

Of another chapter, "Illumination from Paint," it may be truly said that it has revolutionized factory practice in many industries; while the paper on the "Production of Rosin Tung Esters" introduced scientific accuracy into a procedure that, before its appearance, was largely based on guesswork and rule-of-thumb.

The TABLE OF CONTENTS is as follows:

I. Résumé of Soya Bean Oil Investigations. II. Driers for Soya Bean Oil. III. Marine Animal and Blubber Oils. IV. Miscellaneous Fish Oils. V. Changes in Oils Upon Storage. VI. New Foreign Oils. VII. Standards for Tung Oil. VIII. Hexabromide Test for Determining Purity of Linseed Oil. IX. A Method for Determining the Acid Values of Varnishes and Boiled Oils. X. The Effect of Moisture on the Drying of Oils and Varnishes. XI. Fume Loss in Boiling Oils. XII. Fume Control in the Varnish Industry. XIII. Tests of Moisture and Water Resistance of Various Coatings on Small Boat Construction. XIV. New Exposure Tests at Atlantic City. XV. Production of Rosin Tung Esters (Tunga Resin). XVI. Bulking Values and Yield of Pigments and Liquids Used in Paint and Enamel Manufacture. XVII. Oil Absorption of Pigments. XVIII. Fineness and Texture of Pigments. XIX. Metal Powders as Pigments. XX. Primers for Aluminum and Galvanized Iron. XXI. Rare Elements as Paint Pigments. XXII. Waterproof Glues. XXIII. Quick-Drying Lacquer Coatings. XXIV. Notes on the Standardization of Mineral Spirits. XXV. An Emollient for Skin Protection in the Dope and Varnish Using Industries. XXVI. Illumination from Paint. XXVII. Dark Wall Colors for Operating Rooms. XXVIII. Notes on the Effect of Colored Light Upon Plant Growth and Pigmentation. XXIX. Metric Equivalents. XXX. Spreading Rates of Prepared Paint Products. XXXI. A Study of the Practicability of Spray Painting. XXXII. The Preservative Function of Paint and Varnish. XXXIII. Paints for the Home. XXXIV. Paint and Varnish in the Great War. XXXV. Standard Paint Specifications of the War Department. XXXVI. Interdepartmental Specifications.

G. B. HECKEL.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 90. Comparison of Hector Fuel with Export Aviation Gasoline, by H. S. Dickinson, V. R. Gage and S. W. Sparrow, Bureau of Standards. 10 pages. diagrams. quarto. Washington. Government Printing Office, 1920. Aviation engine development for attaining higher power at altitude are following two principal lines, supercharging and increase in compression ratio. For the latter, fuels have been demanded which are capable of operating under compressions too high for gasoline. Among the fuels which will operate at compression ratios up to at least 8.0 without preignition or " pinking " is Hector fuel. whence a careful determination of its performance is of importance.

The Hector fuel supplied by the Bureau of Mines for use in these tests was a mixture of 30 per cent. benzol (C_6H_6) and 70 per cent. cyclohexane (C_6H_{12}). having a low freezing point. and distilling from first drop to 90 per cent. at nearly a constant temperature. about 20° C., below the average distillation temperature ("mean volatility") of the X gasoline.

This comparison of the performance of the two fuels in an aviation engine was made in the altitude chamber at the Bureau of Standards, duplicating altitude conditions up to about 25,000 feet. except that the temperature of the air entering the carburetor was maintained nearly constant at about 10° C. A Liberty 12-cylinder aviation engine was used, supplied with special pistons giving a compression ratio of 7.2 (the compression pressure measured by check-valve gauge was 170 pounds per square inch). Stromberg carburetors were used and were adjusted for each change of fuel, speed, load, and altitude, so as to give the maximum possible power with the least fuel for this power. The tests covered a speed range of 1400 to 1800 r.p.m.

The results of these experiments show that the power developed by Hector fuel is the same as that developed by export aviation gasoline at about 1800 r.p.m. at all altitudes.

Report No. 96. Statical Longitudinal Stability of Airplanes, by Edward P. Warner, Langley Memorial Aeronautical Laboratory, 28 pages, illustrations, quarto. Washington, Government Printing Office, 1920. This report, which is a continuation of the " Preliminary Report on Free Flight Testing " (No. 70), presents a detailed theoretical analysis of statical stability with free and locked controls and also the results of many free flight tests on several types of machines.

In developing the theory of stability with locked controls an expression for pitching moment is derived in simple terms by considering the total moment as the sum of the moments due to wings and tail surface. This expression, when differentiated with respect to angle of incidence, enables an analysis to be made of the factors contributing to the pitching moment. The effects of slip stream and down wash are also considered, and it is concluded that the C. G. location has but slight effect on stability, and stability is much improved by increasing the efficiency of the tail surfaces, which may be done by using an " inverted " tail plane.

The results of free flight tests with locked controls are discussed at length, and it is shown that the agreement between the experimental results and theory is very satisfactory.

The theory of stability with free controls is not amenable to the simple mathematical treatment used in the case of locked controls, but a clear statement of the conditions enables several conclusions to be drawn, one of which is that the fixed tail surfaces should be much larger than the movable surfaces.

The discussion of flight tests with free controls covers the effect of C. G. position, tail setting, and slip stream on the JN-4H and gives an analysis of the curves of forces on control stick for the VE-7, U.S.A.C.-11, and Martin transport.

PUBLICATIONS RECEIVED.

Ontario Department of Mines: Twenty-ninth annual report, being vol. xxix, 1920. Part i. Statistical Review, Mining Accidents in 1919, Mines of Ontario; Second Report of the Joint Peat Committee, A Geological Reconnaissance Into Patricia, Windy Lake and Other Nickel Areas, Halley Burian Intrusive Rocks. Part iv. Kirkland Lake Gold Area, by A. G. Burrows and P. E. Hopkins. Part vi. The Stratigraphy and Paleontology of Toronto and Vicinity. Part i by Beatrice Helen Stewart. 3 vols., illustrations, plates, maps, 8vo. Toronto, King's Printer., 1920.

U. S. Bureau of Mines: Tenth Annual Report of the Director to the Secretary of the Interior for the Fiscal Year Ended June 30, 1920. 149 pages, illustrations, plates, 8vo, Bulletin 117. Structure in Paleozoic Bituminous Coals, by Reinhardt Thiessen. 296 pages, plates, 8vo. Miners' Safety and Health Almanac, 1921, published in coöperation with U. S. Public Health Service for the use of miners. Compiled by R. C. Williams, Assistant Surgeon, U. S. Public Health Service. 48 pages, illustrations, 8vo. Monthly Statement of Coal-mine Fatalities in the United States, October, 1920, by W. W. Adams. 8 pages, 8vo. Technical paper 271. State Mining Laws on the Use of Electricity in and About Coal Mines, by L. C. Ilsley. 51 pages, 8vo. Washington, Government Printing Office, 1920.

National Advisory Committee for Aeronautics: Technical Notes: No. 26, A Variable Speed Fan Dynamometer, by Karl D. Wood, Bureau of Standards. 9 pages, plate, quarto. No. 29, Progress Made in the Construction of Giant Airplanes in Germany During the War, by A. Baumann. 11 pages, quarto. No. 30, Design of Recording Wind Tunnel Balances, by F. H. Norton, Physicist, Aerodynamical Laboratory, N. A. C. A. 6 pages, plates, quarto. No. 37, The Determination of the Effective Resistance of a Spindle Supporting a Model Aerofoil, by W. E. Davidson and D. L. Bacon, Aerodynamical Laboratory. 4 pages, plates, quarto. No. 39, High Thermal Efficiency in Airplane Service, by S. W. Sparrow, Automotive Power Plants Section, Bureau of Standards. 5 pages, plates, quarto. Washington: Committee, 1920.

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GUIDED-WAVE TELEPHONY.*

BY

CHAS. A. CULVER, Ph.D.,

Canadian Independent Telephone Company, Ltd., Toronto.

INTRODUCTION.

CERTAIN discoveries or achievements in the realm of science stand out preëminently as marking the beginning of new epochs in the world's progress. Such was the invention of the magnet telegraph by Morse, the telephone by Bell, the discovery of radioactivity by Becquerel, electromagnetic waves by Hertz, and X-rays by Röntgen; the invention of the audion by DeForest and guided-wave or high-frequency multiplex telephony and telegraphy by Squier.

Prior to General Squier's invention it had been possible to simultaneously transmit several telegraph messages over a single telegraph circuit, and while certain earlier attempts had been made to develop a system of syntonic multiplex telegraphy, it is to the man who is at present Chief Signal Officer of the United States Army that the world owes the invention of a system of communication by which it is possible to carry on as many as ten or more two-way simultaneous telephone conversations over one electrical circuit. In 1910 Major General Squier (then Major), by a bold and ingenious adaptation of the fundamental principles and appa-

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* Presented at the Stated Meeting of the Institute held Wednesday, November 17, 1920.

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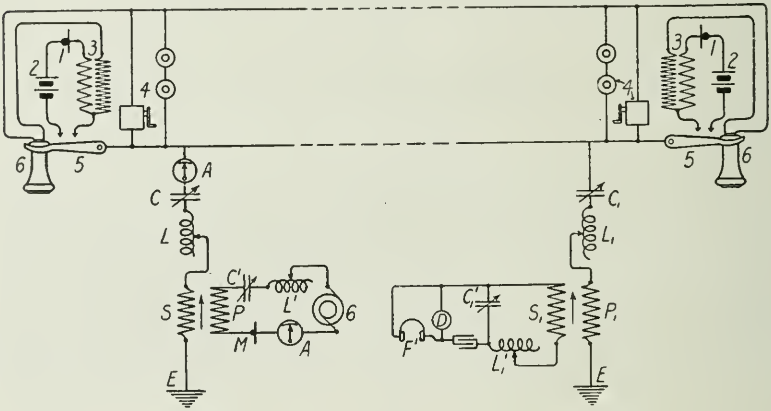
ratus previously employed in radio-telegraphy and telephony, developed the multiplex system which bears his name, and thereby established a distinct branch of the art of communication.

PRINCIPLES INVOLVED.

The fundamental principle underlying the Squier system of multiplex telephony is that of high frequency electrical resonance. Previous attempts to solve the multiplex problem had been based, largely, on electro-mechanical resonance.

Figs. 1 and 2 are reproduced from Squier's original disclosures. Fig. 3 is a simplified diagram illustrating the fundamentals involved. A source of continuous high frequency electromagnetic waves of definite frequency are impressed upon the physical circuit by means of the air core resonance transformer $L_1 - L_2$. By means of the variable condenser C_1, the circuit consisting of the two parts of the line and the bridging elements just referred to is brought into electrical resonance with the impressed high frequency E.M.F.

FIG. 1.



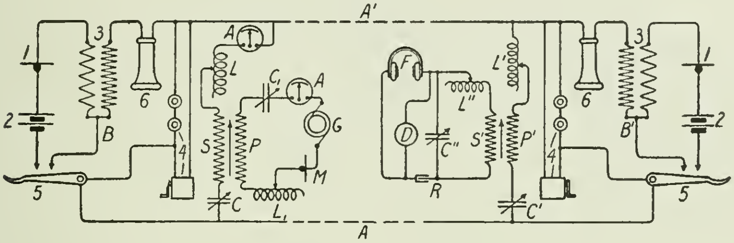
Referring to the well-known relation

$$I = \frac{E}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

it is evident that the current in the line will be a maximum when resonance obtains; that is, when the inductive reactance equals the capacity reactance or $\omega L = \frac{1}{\omega C}$. This condition will be indicated by the reading of the ammeter *A*. Fig. 4 shows two typical resonance curves made from data secured in actual engineering practice.

In Squier's original investigations the source of high frequency energy (see Figs. 1 and 2) was a high frequency alternator.

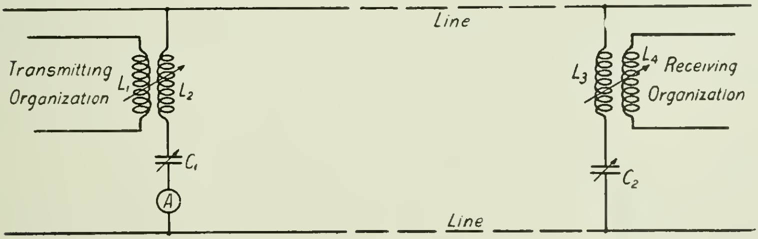
FIG. 2.



The impressed energy was voice modulated by means of an ordinary microphone, thus giving rise to a modulated high frequency "carrier wave" in the physical line.

To detect and translate this "carrier wave" at the receiving end of the line, a circuit arrangement similar to that shown at the right of Fig. 3 is employed. The local receiving organization is inductively coupled to the line through the air core resonance transformer $L_3 - L_4$. In adjusting the receiving equipment to abstract maximum energy from the line the bridging elements L_3C_2 are adjusted to resonance with the frequency of the carrier wave and the local translating circuit is likewise adjusted to resonance with circuit L_3C_2.

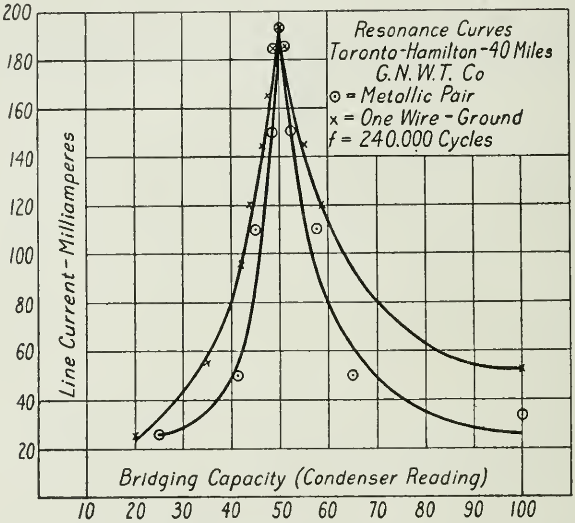
FIG. 3.



The voice current is recovered from the modulated carrier wave by means of a primitive audion hook-up as shown in Fig. 5.

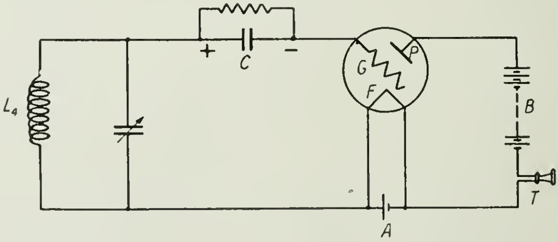
This will be discussed in detail later. At this point it suffices to note that the receptor is an integrating translator, which delivers to the telephone receiver a varying unidirectional current corresponding to the voice current supplied to the modulating device at the transmitting station.

FIG. 4.



It is thus evident that we have the elements of a radio-telephone installation, the essential difference being that in place of the connections to earth and the usual antenna, we have, in this case, connections to the two wires constituting a physical pair. The two fundamental factors, then, in the Squier system of multiplex are *the utilization of electrical resonance and the use of an integrating translator.* Whether the frequency of the carrier

FIG. 5.



current is low or high does not modify the basic principles involved. In this system electromagnetic waves of predetermined length are guided by the metallic circuit, instead of radiating in all directions from an antenna. While there undoubtedly is a certain amount of radiation from the physical line, the over-all efficiency of the guided-wave system is obviously materially higher than in the case of a free-wave system. This is thoroughly confirmed by experience.

DELAY IN PRACTICAL APPLICATION.

Following the original disclosures by General Squier, the author, and doubtless others, began the study of this new method of communication. During 1913–15 the writer conducted a series of guided-wave telegraphic tests over the telegraph lines of the Chicago, Milwaukee and St. Paul Railway and the Delaware, Lackawanna and Western, employing damped-waves and comparatively crude equipment. These experiments established the fact that guided-wave telegraphy over practical distances between stations, and between stations and moving trains, was possible. Telephony by this means was not attempted because equipment for producing undamped waves was not available.

Indeed one of the principal factors which tended to delay [1] the practical application of this new system was the nature and cost of the power unit. The inventor in his original investigation had at his disposal one of the two high frequency alternators existing on this continent.

This, however, was not the only reason why the Squier system of multiplex did not come into commercial use until a comparatively recent date.

A paper by General Squier describing in detail the original investigations connected with his invention was read before the Chicago meeting of the A.I.E.E. on June 28, 1911. This paper was later published as a professional paper of the Signal Corps of the U. S. Army. A critique of this paper by Doctor Jewett, Chief Engineer of the A. T. & T. Co., and others, also appeared in the issue of the Proceedings of the A.I.E.E. which carried the original paper by the inventor.

In his criticism of the Squier method of multiplexing Doctor

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[1] Squier's U. S. patents are dated Jan. 3, 1911.

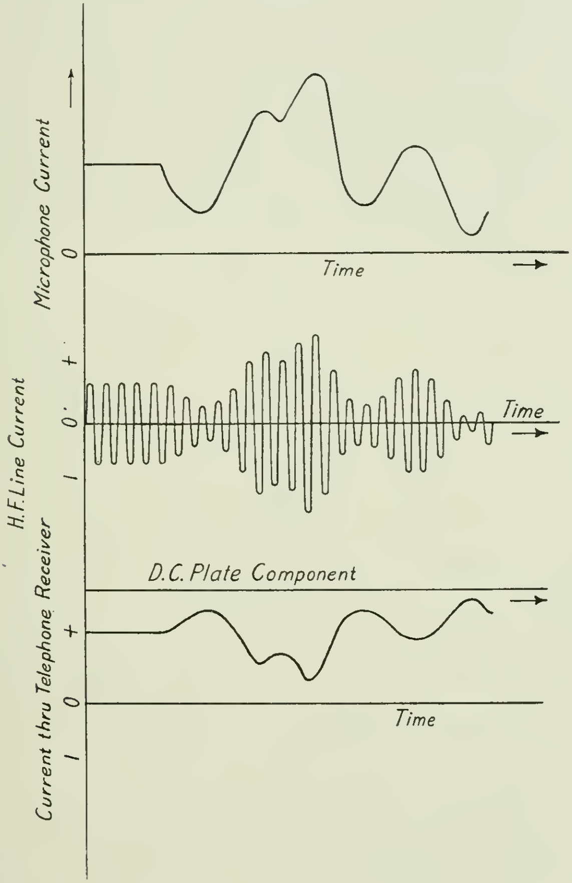
Jewett took the position that the use of a carrier wave of comparatively high frequency would be impracticable owing to the extremely great attenuation which would obtain. We shall refer in a later paragraph to Doctor Jewett's comments. It suffices here to say that it is more than probable that the adverse criticism by so eminent an authority in the telephone art as Doctor Jewett effectively served to discourage, for a considerable period of time, those who might otherwise have been inclined to give practical application to General Squier's invention. Subsequent events have clearly shown that this criticism was not well founded. Indeed the system of multiplex developed by General Squier is understood to be at the present time in commercial use by the A. T. & T. Co. and is being rapidly extended by this and other commercial interests throughout the world.

THE THREE-ELECTRODE TUBE AND ITS RELATION TO MULTIPLEX.

Reference has been made to the nature of the source of high frequency current originally available. Owing to the exigencies of the war, the audion, invented by Doctor Lee deForest, came into wide use in the radio art as a detector and amplifier. It also came to be extensively used as a source of high frequency alternating current, and as a modulator of such currents. As before indicated, the invention of the three-electrode thermionic tube marked an epoch in the art of communication, and the development and perfection of this device as a simple and inexpensive generator of high frequency alternating currents made possible the wide practical application of the Squier system of multiplex.

In order to clearly outline current engineering practice in this new art it is necessary to briefly review certain fundamentals connected with the audion, or three-electrode thermionic valve. Recalling the well-known characteristic of such tubes, *viz.,* that only negative charges (electrons) pass from the filament F (Fig. 5) to the plate P, it is obvious that any negative charge on the central electrode will tend to diminish to migration of electrons from F to P. In short, if the grid G is caused to vary in potential the current in the circuit $P\ B\ T\ F$ will vary in a corresponding manner. Further, if the tube forms part of an organization, as shown in Fig. 5, and an alternating E.M.F. is developed in the inductance L_4, the condenser C will become charged as shown. It is thus evident that the audion is an integrating device. If an alternating E.M.F. of varying amplitude be developed in the inductance L_4 by associating said inductance with the bridging inductance L_3, as shown in Fig. 3, the audion [2] will serve to integrate and translate the carrier wave into a varying unidirectional current in the circuit containing the telephone receiver *T*, Fig. 5. This process is graphically shown in Fig. 6. It is seen from the last curve in the figure that the current through the receiver corresponds to

FIG. 6.



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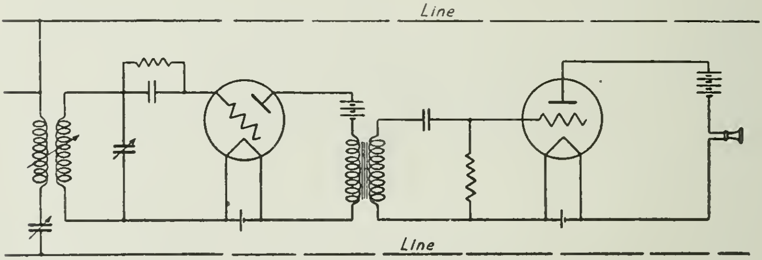
[2] It is probable that General Squier was the first to use the audion in connection with speech or telegraphic transmission over physical circuits.

the envelope of the line current. In this manner the voice current is "recovered" from the high frequency carrier current which is guided by the physical circuit.

From the foregoing remarks regarding the audion it is evident that the device is inherently a repeating and an amplifying agent. Since the plate circuit accurately reproduces the potential variations in the grid circuit it thus becomes possible to magnify or amplify the energy originally supplied to the grid-filament, the local battery *B* supplying the necessary energy. Thus if the mean value of the amplitude of the carrier current is too small to give a tone intensity of commercial value in the telephone receiver *T*, we may arrange to have the output from the first detector tube feed the grid-filament circuit of a second audion through a suitable transformer as shown in Fig. 7.

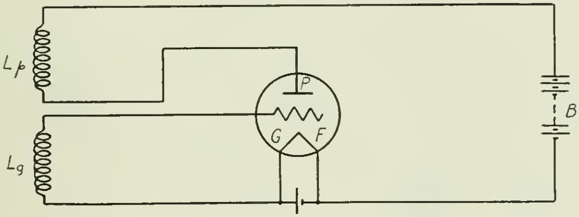
FIG. 7.



If greater magnification is required several such amplifying tubes are connected in series. However, because of various electrical disturbances in the physical circuit, it is found impractical to use more than two amplifying tubes, when connected as shown, in addition to the original detecting or translating tube.

It is, however, with the audion as a generator of high frequency alternating currents that we are principally concerned. Recalling the repeating and amplifying characteristics of the audion, it is easy to see that conditions may be so arranged that the plate circuit will react upon the grid circuit and thus automatically effect a variation in current in the plate circuit itself. Referring to Fig. 8, if an inductance L_p, for example, be inserted in the plate circuit any variation in the potential of the grid will, as before indicated, result in a variation in the current in the plate circuit and hence a change in the potential at the terminals of the inductance L_p. Since L_p and L_g are inductively associated, this potential variation in L_p will cause a corresponding variation in L_g, and hence in the potential of the grid. This change will again cause a change in I_p, which will again react to cause a change in E_g. It is thus evident that there has been initiated an electrical cycle of operations which tends to repeat itself indefinitely, the energy necessary to sustain this cycle being derived from the battery B. The cycle usually starts automatically with the closing of the filament circuit. The frequency of the cyclic process is governed by the value of the inductances in the plate and grid circuit and any associated capacity. In short, the audion thus becomes a source of alternating current, energy being abstracted from the audion organization by associating with it an independent resonant circuit (see Fig. 10) or by electrostatically coupling to an energy-absorbing system. The simplicity and constancy of such a source of alternating current makes guided-wave telephony a practical every-day accomplishment.

FIG. 8.



Not only does the audion act as a generator of high frequency alternating currents and a detector of the same, but it may also functionate as a modulating device.

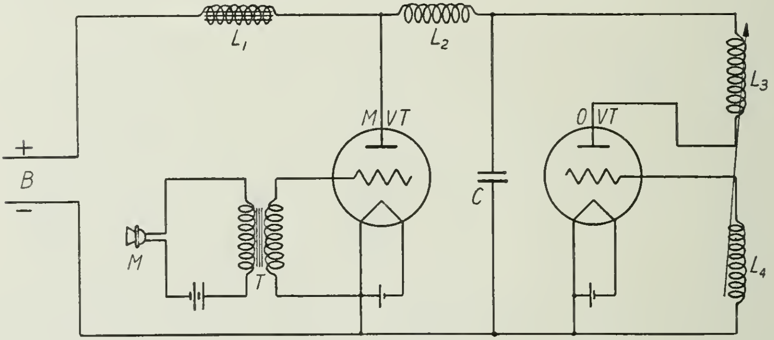
Speaking broadly, there are three general methods of utilizing the audion for the purpose of impressing the ordinary microphonic voice current upon the high frequency carrier current.

One of the most commonly used arrangements for accomplishing this is shown in Fig. 9.

This circuit is variously called the "choke coil," "constant current" and "Heising" method. By referring to Fig. 9 it will be noted that there are two tubes in parallel, the plate voltage being supplied by a D.C. generator or rectifier unit. The power tube *OVT*, together with the associated circuit $L_3C_2L_4$, constitute the high frequency oscillating circuit. The air core choke L_2 prevents the high frequency current from passing back through the generator and modulating units.

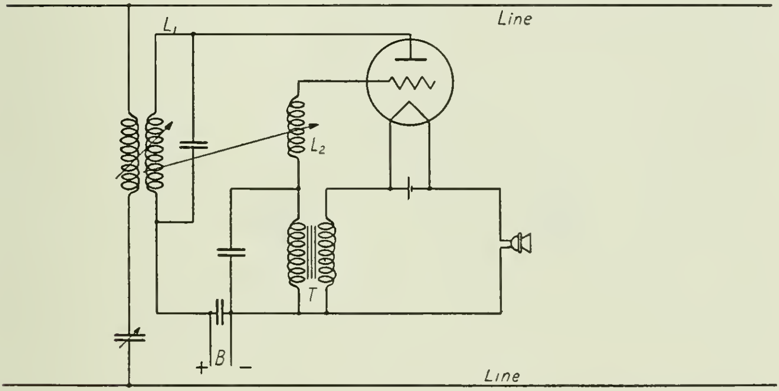
The tube MVT, and the associated microphone M and transformer T, form the modulating unit. If the microphone M be spoken into an alternating E.M.F. will be developed in the secondary of the transformer T, the wave form of this E.M.F. corresponding to the upper curve in Fig. 6. The grid, or control electrode, of the modulating tube is thus subjected to a varying potential. As previously pointed out, this will result in what amounts to a variation in the internal resistance of the modulating tube MVT. Therefore, the current passing through the tube between the plate and filament will vary in a corresponding manner. Because of the presence of the choke coil L_1, the total current drawn from the D.C. generator cannot change rapidly, and since the two audions are in parallel, it follows that if the current through the tube MVT increases, that through OVT must decrease, and *vice versa*. Thus the power supply to OVT will be modified in conformity with the voice current impressed upon the modulating tube. It therefore follows that the output of the oscillating power tube will likewise vary, and thus the carrier wave emitted by the circuit $L_3C_2L_4$ will vary in amplitude, or, as it is usually expressed, be modulated. This method of modulation is very satisfactory for units of small output, but possesses the disadvantage that at least two tubes are required.

FIG. 9.



A second method is known as " direct grid " modulation. A circuit operating on this principle and which gives good results in guided-wave practice is shown diagrammatically in Fig. 10. In this case the microphone is coupled through the modulating transformer *T* directly to the grid of the oscillating power tube. The potential of the grid will thus be caused to vary in conformity with the microphonic voice current, and the power output of the tube will vary in a corresponding manner. With the particular circuit shown the completeness and accuracy of the modulation of the emitted carrier wave is largely determined by the mutual inductance between the plate and grid coils L_1 and L_2. The method of modulation just outlined possesses the advantages that but one tube is required, and that the modulation may be easily adjusted.

FIG. 10.

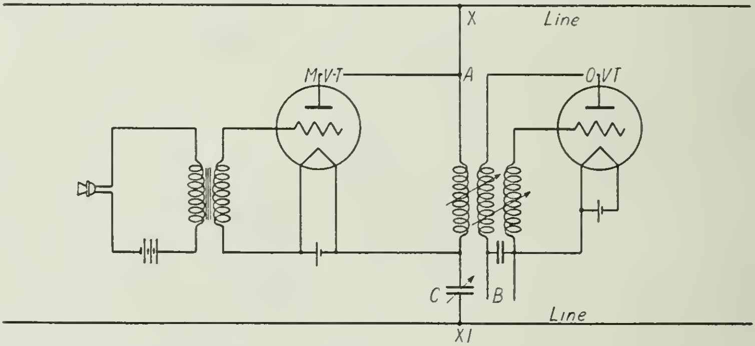


The third general method of utilizing the three-electrode tube as a modulating agent is shown schematically in Fig. 11. In this organization the plate circuit of the modulator tube is connected as a shunt to a part or all of the secondary or bridging inductance *L*. The variations of the grid potential effected by the associated microphonic circuit causes the modulating tube to act as a variable resistance in parallel with this inductance and thus tends to functionate in part as an energy absorbing agent and in part as a detuning device. The result is that the energy supplied to the line by the oscillating tube is caused to vary in accordance with the original microphonic current.

This system possesses the disadvantage that at least two tubes are required and also that the modulation is more or less incomplete thus resulting in a comparatively low value of tone intensity at the receiving end. Incidentally it may be added in this connection, that a more satisfactory "absorption" arrangement in guided-wave practice is to insert the microphone itself directly in the bridging circuit, either between X and A or between C and X_1.

From what has been said in outlining the behavior of the three-electrode tube as a detector, an amplifier, an oscillator and a modulator, the present method of accomplishing high frequency multiplex telephony is more or less obvious. We may, for example, bridge across a physical telephone or telegraph pair or between a single wire and the ground, several transmitting organizations similar to that shown in Fig. 10, each transmitting unit being permanently adjusted to deliver to the line a voice modulated high frequency current of a definite and fixed periodicity. At the receiving end of the line a corresponding number of receiving units, similar to that shown in Fig. 7, are bridged across the same physical circuit. Each receiving unit is "tuned" or brought into electrical resonance with a certain transmitting set. Speech may then be carried on over any one or simultaneously over all of these super-channels. Each party to a conversation utilizes a carrier frequency, two such frequencies being required for a two-way conversation. When the carrier waves are properly selected there is no mutual interference or "cross talk" between the super-channels; neither are the guided-wave conversations heard in the ordinary physical telephone apparatus, and the transmission over the physical circuit is inaudible in the multiplex equipment.

FIG. 11.



NUMBER OF SUPER-CHANNELS.

The maximum number of two-way guided-wave channels, which may be simultaneously operated over a single physical circuit, depends somewhat upon the electrical constants of the particular line and also upon certain inherent limitations of the multiplex system itself.

It was noted above that two carrier waves are usually employed for carrying on a two-way conversation. As a result of the well-known principle of interference, if two alternating currents coexist in a physical circuit, there will also obtain a third alternating current whose frequency will be equal to the numerical difference between these two original frequencies. If the two primary frequencies are near enough together, the resulting "beat" frequency will have a value which, if the resultant current reaches the receiving apparatus, will manifest itself as a high-pitched note. In short, an electrical " beat tone " will exist, and, unless eliminated by means of elaborate electrical filters, will prove to be a disturbing factor in the guided-wave telephonic transmission. When it is recalled that the average human ear can begin to sense a tone when its frequency is not greater than 20,000, it will be evident that the frequencies of the two-carrier waves utilized for a two-way conversation must differ by at least 20,000. For example, if one-carrier frequency is 100,000, the other carrier frequency must either be 80,000 or 120,000.

Further, it will also be obvious that the lowest carrier frequency which can be used must be greater, theoretically at least, than this upper limit of audition, *viz.*, twenty thousand. In practice, however, it is found that a fundamental carrier frequency of about 15,000 may be used.

The upper practical limit of carrier frequency has not yet been definitely determined. As before indicated, it was maintained by those who originally attempted to point out the limitations of this system of communication that, owing to supposed attenuation effects, frequencies of the order of 100,000 would be entirely impracticable. The engineering research of the Signal Corps and of the writer has clearly demonstrated that frequencies of the order of 500,000 are entirely practical. There is reason to believe that frequencies as high as one million per second may possibly be utilized in multiplex practice.

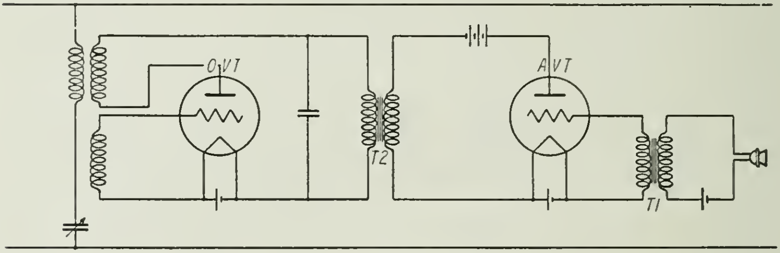
However, as a basis of discussion, if we take the limit as

15,000 and 500,000, respectively, and remember the further limitation imposed by the possibility of "beat notes" between the fundamental carrier frequencies or between the first harmonic of one carrier wave and the fundamental of the next, it follows that at least six simultaneous guided-wave two-way conversations are entirely practicable over a single physical circuit—and this in addition to the usual two-way telephone or telegraph traffic.

It, therefore, follows that we have here a system of communication which makes it possible to increase the telephonic traffic-carrying capacity of a given line at least sixfold, and, when distances of the order of 100 miles or more are considered, at a cost substantially lower than that necessary to construct and maintain additional physical lines.

There is reason to believe that the number of high frequency multiplex telephone channels that may be superimposed upon a single physical circuit may, in the near future, be doubled.

FIG. 12.



It is possible to arrange a circuit of such a character that it will deliver high frequency currents to the line only when conversation is taking place.[3] With such an arrangement both parts of a two-way conversation could take place on carrier waves of the same frequency; in fact, true duplexing would obtain. Therefore instead, for example, of six simultaneous two-way conversations it would be possible to establish twelve super-channels. A circuit which is said to accomplish this end is shown in Fig. 12.

By reference to the figure it will be noted that the voice current is amplified by the tube *AVT*, and that the plate circuit of this amplifying tube supplies energy to the primary of the audio-frequency transformer T_2. The secondary of this transformer serves as a source of anode potential for the oscillating power tube OVT. It is thus evident that the high frequency power circuit will not deliver energy to the line except when sound waves impinge upon the microphone.

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[3] See General Electric British Patent No. 15.237–1915. Also "High Frequency Multiple Telegraphy and Telephony on Wires," by H. Fassbender and E. Habann, *Jabrh. d. Drahl, Tele.*, Oct., 1919.

The author has designed a circuit of such a nature that the tube which acts as a high frequency oscillator will also serve as a detector, thus making it possible to utilize the same tube for both transmission and reception.

This step has been made possible as a result of the discovery by the author that it is possible to design a circuit of such a nature that it will oscillate without any "B" potential, in the commonly accepted sense of the term. Further, this new circuit may be so adjusted that the "regenerative" state will obtain, thus making the organization highly sensitive as a detector.

By properly associating a microphone and a telephone receiver with this new circuit, it has been found possible to design an organization such that one tube functionates as both oscillator and detector, and further that no energy is delivered to line except when one speaks into the microphone. While the engineering development work on this new circuit has not reached the point where equipment is manufactured on a commercial scale, yet the result of the experimental work this far carried out justifies the statement that it is possible to design a practical multiplex telephone unit of comparatively small size, and which will serve to double the number of high frequency multiplex conversations which may be simultaneously carried on over a single physical circuit.[4]

In considering the question of the maximum number of super-channels between any two points, the problem arises concerning the utilization of adjacent physical circuits on the same pole lead. Experience has shown that under certain conditions there is no cross-talk between adjacent parallel super-channels, while under other conditions cross-talk will obtain. It has been found that excessive transpositions are unnecessary. It is therefore possible to operate high frequency super-channels over adjacent parallel physical circuits. If traffic conditions are such that it is unnecessary to utilize more than one physical circuit on a pole lead as a basis for super-channels, and conditions are such that high frequency cross-talk occurs between adjacent metallic circuits, the natural procedure is to electrostatically connect the several physical pairs in parallel through the high frequency bridging circuits, thus collecting and utilizing a part of the energy which would otherwise be wasted.

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[4] The author gave a practical demonstration before the Institute of a two-way conversation by means of his newly designed circuit.

CONDUCTORS WHICH MAY BE USED.

In considering the utilization of the various metallic circuits which may serve to guide the high frequency carrier currents, we come to a consideration of the effect of the material constituting the physical circuit.

Experience has shown that copper, copper-clad iron, and aluminum wire may be used. It has been found in practice that solid copper and copper-clad conductors of equal surface area have practically the same conductivity and hence serve equally well as guiding media for high frequency carrier waves. Ordinary galvanized iron wire, however, will not answer. It has been found, for example, that twelve miles of No. 12 galvanized iron telephone wire will completely obliterate all resonance effects, and that it is not possible to effect a transfer of energy unless frequencies of the order of 20,000 are employed. These practical results are consonant with the effects which may be predicted from theoretical considerations. Preuner and Pungs[5] have shown by measurements that the zinc coating on iron wire must be substantially thicker than that of a copper exterior to effectively shield the iron core.

It is of both theoretical and practical interest to find that high tension power lines may be utilized as guides for high frequency carrier waves, and without any interference to multiplex telephonic transmission from the low frequency power currents.

In making use of a power line to establish guided-wave telephone service, the high frequency equipment is electrostatically coupled to the power line by suitable high tension condensers or by connecting directly to a wire of a few hundred feet in length, supported parallel to and within a few feet of the power wires and thence to earth. A system employing the first method has been in practical operation in Japan[6] for more than a year. An installation[7] utilizing the second plan mentioned is in use in Germany. The practical utility of this aspect of guided-wave communication is obvious.

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[5] "Electro-plated Iron in High-Frequency Fields," by G. Preuner and L. Pungs, *Verhandlungen der Deutschen Physikalischen Gesellschaft*, Sept., 1919.

FUNCTIONING OF A PHYSICAL CIRCUIT AS A H.F. CARRIER.

In considering telephonic transmission by means of carrier currents the general behavior of physical circuits as high frequency channels becomes of prime importance.

One of the first factors which commands one's attention is the fact that in high frequency work a physical line acts as a lumped capacity. In other words, at radio frequencies the line reactance is in the nature of a capacity instead of an inductance. There is abundant evidence of this. The capacity of a 100-mile No. 10 aerial telephone pair is approximately 0.8 M.F., and this line capacity is in series with the bridging inductance and capacity of the connected h.f. unit. Since the latter has a value of the order of 0.001 – 2 M.F. the bridging circuit should act when connected to the line as though shorted by a condenser of relatively large value. Such is found to be the case in practice. The setting of the bridging condenser is the same whether the apparatus is connected to a line fifty miles or several hundred miles in length.

Indeed, it has been observed that a transatlantic cable will give practically the same resonant setting on the bridging condenser as will a circuit of a few hundred feet in length. Further, since the change in capacity due to a difference in the size of line wires is small compared with the total capacity of a line, and since as shown above, the line capacity is in series with the h.f. bridging capacity, it will not appreciably alter the tuning of the g-w. telephone set if it becomes necessary, owing to operating conditions, to connect the h.f. equipment to various metallic circuits. The resulting element of practical operating flexibility is thus apparent.

In General Squier's original paper, before referred to, the conclusion is reached that the line reactance is in the nature of an inductance, rather than of a capacity. That conclusion was reached because the capacity reactance of the bridging condenser at resonance exceeded as computed, the inductive reactance, and since at resonance the capacity and inductive reactances should be equal, it was thought that the line reacted in such a manner as to supply the difference. There appears, however, to be an error in the above point of view. Mutual inductance undoubtedly existed between the coupling inductance P and S, Figs. 1 and 2, in General Squier's organization. Hence in computing the inductance value the mutual inductance should have been considered.

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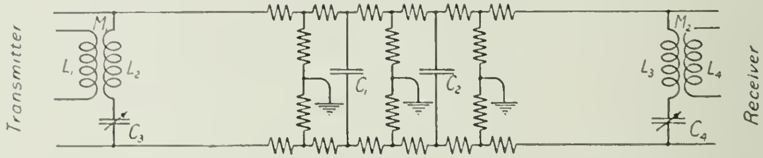
[6] "Simultaneous Transmission and Reception in Radio Telephony," by Noboru Marumo, *P. I. R. E.*, Vol. 8, No. 3, June, 1920.

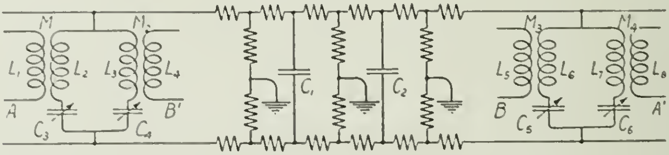
[7] "H. F. Telephony in High Voltage Overhead Power Distributing Systems," by Gewecke, *Elektrotechnische Zeitschrift, 41,* Aug. 26, 1920.

FIG. 13a.



In dealing with the inductance and capacity factors, the line as a whole must be considered. The line organization appears to resolve itself into two resonant circuits having electrostatic coupling. Fig. 13*a* probably represents the several factors (except radiation resistance) as they obtained in General Squier's original experiments, and Fig. 13*b* as they obtain in a simple case in actual g-w. practice. In the latter Fig. *A* represents a transmitting unit and A_1 the corresponding resonant receiving unit; *B*, the second transmitter, and B_1 the corresponding receiving organization. So far as the g-w. organizations at the left of the figure is concerned, the first mile or less of the physical line determines the effective line capacity C_1, and in a corresponding manner C_2 is related to the coupled system at the right.

FIG. 13b.



As additional experimental proof of the above tentative theory regarding the functioning of a physical circuit as a high frequency channel, it may be noted that the physical line may be "dead shorted" at some point between the two terminal stations without interrupting commercial conversation on the h.f. channel. Further, if the bridging circuit of a given transmitting set is adjusted to give maximum line current, and the tuning of the receiving organization, including its bridging circuit, be changed, it becomes necessary to readjust the transmitter circuits in order to maintain a resonant condition with the line.

INTERFERENCE.

In discussing the possibilities and limitations of g-w. telephony, the question of interference naturally arises. This point has been partially covered in the discussion concerning the use of power lines as h.f. channels. It may be added in this particular connection that experience has shown that 110,000-volt 25-cycle power lines running parallel to, and at some points within 50 feet of, the physical telephone system, produce no interference whatever in the g-w. super-circuit.

It has also been found that g-w. telephone channels may be successfully operated over a telegraph circuit which is being used for Morse duplex or for duplex printer operation.

There is a possibility of interference from continuous wave radio stations. This may result from the fact that the frequency of the wave, emitted by an undamped radio station, may chance to be near (within about 20,000 cycles) the frequency of a multiplex telephone carrier wave. The physical circuit which serves as a basis for the h.f. super-channels will act as an antenna and thus intercept enough energy to produce a heterodyne effect with the undamped g-w. telephone wave. In short, the effect in the g-w. telephone receiver will be exactly the same as when two g-w. telephone waves combine to form a "beat note," as previously discussed.

Spark radio stations may also be heard in the g-w. telephone apparatus if the carrier wave used has the same value as the wave emitted by the radio station. This is particularly true if a single line wire and earth return is being used for the super-channel.

Since, however, the wave-lengths of all radio stations are known, it is a comparatively easy matter to avoid radio interference, if such exists in any given case, by not using as carrier currents those waves which are near in frequency to the interfering radio wave.

With regard to atmospheric and other irregular extraneous electrical disturbances, commonly spoken of as "static" in the radio art, it may be said the guided-wave system is no more subject to interference from this source than is the ordinary telephone organization. When utilizing untransposed and poorly insulated telegraph circuits as guides for h.f. carrier waves, the interference due to atmospheric disturbances is naturally more marked than when connection is made to well-constructed telephone circuits. However, interference is, in general, decidedly less marked than in the case of radiotelephony. The author has never experienced but one occasion when communication by g-w. telephony was interrupted by vagrant disturbances in the line, and this was when using a telegraph circuit as a guiding channel.

ATTENUATION AND EFFICIENCY.

In considering the system of guided-wave telephony perhaps the most interesting, and from a purely scientific point of view, the most significant, is the question of the absolute and relative magnitude of the energy required to effect commercial communication by this means.

Let us first compare the over-all efficiency of g-w. telephony with radio telephony. Using one hundred miles, and no extra-detector amplification, as a basis for comparison, we find that experience shows that, when operating under average over-land conditions, radio telephonic communication can be effected if the transmitting apparatus delivers one hundred watts to the radiating system. This gives us a mean energy-distance ratio of one watt per mile.

In the case of g-w. telephony extensive engineering tests have shown that when utilizing a carrier current having a frequency of the order of 125,000 cycles, commercial communication can be maintained if the equipment will deliver five watts to a well-constructed physical telephone circuit consisting of a pair of No. 10 copper aerial wires. This gives a mean energy-distance ratio of 0.05 watts per mile. It will thus be seen that the g-w. system is twenty times as efficient as radio telephony.

In making the above comparison, it was assumed that neither the radio nor g-w. apparatus was connected to local land lines. If connection were made to local physical circuits an additional amount of energy would be required in both cases for the purpose of amplifying the voice currents. As this would be of the same order in each case, and since its value would be a more or less fixed quantity and independent of the distance separating the h.f. stations, it has been omitted from the comparison.

In passing to a consideration of the comparative efficiency of guided-wave transmission and communication by means of ordinary telephony, we come to the most vital part of our subject. This aspect of our discussion involves the question of attenuation, and again brings before us the original criticism of Doctor Jewett and others.

Doctor Jewett says[8]: "Further, a few simple computations will show that the attenuation of current at the high frequency which must be used in Major Squier's system is enormously greater than the attenuation at the frequencies which go to make up ordinary speech. The phenomena of current attenuation on long telephone circuits are not different in character for frequencies of from 15,000 to 100,000 periods per sec. than for frequencies of from 200 or 300 to 3000 per sec. *and the same attenuation formulas can be used.*" (The italics are mine.) On this assumption, Doctor Jewett then proceeds to compute both the low and high frequency attenuation constants for several sized conductors. Both computation and engineering experience show, however, that the attenuation in h.f. transmission is not of the order indicated by Doctor Jewett's computations. It would appear that a serious error was made by Doctor Jewett in assuming that the standard attenuation formula applies in the case.

It is, however, a matter of experience that frequency *does* enter into the determination of the power-distance ratio. How, then, can this fact be reconciled with the above analytical relation?

In dealing with high frequency currents on physical conductor a certain amount of energy is in all cases *lost by radiation.* There is abundant empirical evidence that such radiation obtains in the case of h.f. carrier waves on telephone and telegraph circuits. Indeed, it has been found possible to establish h.f. telephonic communication between a moving train and a fixed station, the latter utilizing a physical circuit along the right of way as a h.f. wave channel. A part then of the energy originally delivered to the line by the terminal apparatus is lost by radiation.

It is difficult to determine the law of radiation which obtains in the case of a physical circuit whose length is many times the wave-length of the h.f. carrier wave. The problem is rendered particularly complex because of the fact that the physical circuit in question may be only one of a considerable number of other metallic circuits on the same pole lead, thus greatly modifying the electrostatic and magnetic field about the conductor.

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[8] Multiplex Telephony—Discussion, by Frank B. Jewett, A. I. E. E., Vol. xxx, Part ii, 1911.

The dissipation of h.f. energy in a non-transposed telegraph circuit has been found by comparative tests to be very much greater than in the case of a transposed telephone circuit made up of the same sized conductors. There is some evidence for believing that the loss of energy is modified by the number of transpositions in the line. It is possible that a twisted pair would functionate advantageously. This explanation, however, is only tentative, not having been fully established.

In the above discussion reference has only been made to open aerial lines. In the case of cables the dissipation of energy is due to dialectric loss, eddy currents in the cable sheath, and radiation, with the result that the attenuation in cables is somewhat higher than in open lines. The opinion appears to obtain that the attenuation in cables is prohibitive. Practical experience shows that such is not the case. Our experience in working with frequencies up to 500,000 over lines, which included between two and three miles of cable, shows that it is unnecessary to terminate the h.f. super-channel at the end of the open aerial line when establishing h.f. multiplex service between cities.

In addition to the energy lost by radiation, there must also be considered the question of high frequency insulation resistance. Insulation which may have a high value for direct or low frequency E.M.F.'s frequently exhibits low values when h.f. pressures are involved.

Referring to equation 3 above, it is therefore evident that the value to be given to G is at present indeterminate. The relation for h.f. attenuation which is finally evolved will probably contain a term or terms corresponding to G, and which will account for radiation and leakage. This term will undoubtedly prove to be a function of the frequency. Additional data must be at hand before such a working relation can be developed. Progress is, however, being made both analytically and empirically along this line.

The incorrectness of Doctor Jewett's attenuation values are even more strikingly shown when one examines the energy ratios which he evolves.

For instance, he states that 300,000,000 times the energy would be required to telephone by means of a h.f. 50,000-cycle carrier wave for a distance of 1000 miles, over a non-loaded No. 8 B.W.G. copper circuit, than would be required for equal communication by ordinary telephonic means.

If we assume that the energy supplied to the circuit by the regular telephone transmitting organization is of the order of one watt, it is evident, on the basis of Doctor Jewett's assumption, that 300,000 K.W. would be required to effect equally good transmission by the high frequency means.

Now, 50,000 cycles correspond to a 6000-metre wave, and it is a matter of common knowledge that direct radio-telephonic communication can be established when using a wave of this order with the expenditure of an amount of power not to exceed one three-thousandths part of that indicated by Doctor Jewett. In view of the fact that communication by means of h.f. carrier waves is several-fold more efficient than by direct radio, Doctor Jewett's figures are plainly erroneous.

As before indicated, it has been established that when utilizing a carrier frequency of the order of 100,000 cycles, the energy input required in guided-wave telephony does not exceed five watts for the first one hundred miles. Though we do not at present know the complete law relating energy and distance in guided-wave practice, there is evidence for believing that the falling off of energy is not *more* rapid than indicated by an inverse square law. On this assumption it would require a h.f. input to the line of something like 500 watts to cover a distance of 1000 miles, repeaters and extra-detector amplification not being used.

Further, in making the original comparisons of the guided-wave system with ordinary telephone practice, the critics apparently failed to take account of the fact that the audion, which forms an essential part of the Squier system, is inherently an amplifying device, and therefore, does not require as great an energy input from the line as does the ordinary telephone organization. Their original premise was, therefore, incorrect.

Unfortunately, it is not easy to set up artificial high frequency lines, and thus be in a position to make h.f. transmission measurements in the laboratory. This is due chiefly to the fact that it is difficult to simulate radiation as it exists in guided-wave practice. Progress is, however, being made along these lines and there is reason to expect that important disclosures concerning the laws governing h.f. transmission will be made in the near future. The factor that has tended most to inhibit progress in the high frequency field is our preconceived notions. We have failed to realize that, in high frequency work, we are dealing with phenomena which follow, in many cases, entirely new and unknown laws, and that we are led into serious errors when we attempt to apply laws which obtain in low (audio) frequency practice.

In this general connection the author is reminded of one or two typical instances of traditional scientific beliefs. Several years ago the writer suggested to one of the leading radio physicists that possibly one could abstract energy from the electromagnetic waves employed in radio communication by placing a long horizontal wire just above the surface of the sea. The scientist referred to held that such a system would not functionate as a receiving antenna because it would practically coincide with a surface of good conductivity. We know now that submarine craft communicate by radio when running awash and also when submerged.

During the war the writer suggested to one of the prominent research engineers that possibly the power required to effect transatlantic radio communication could be materially reduced if the ground connections of two such stations were made to the sheath of the same transatlantic cable. It was thought that the cable might serve to guide and confine the electromagnetic waves to a narrow channel rather than allowing them to spread in all directions. The engineer did not concur in the suggestion, basing his arguments upon laws which obtain in the case of direct and low frequency alternating currents.

We are still of the opinion that the suggestion is worth trying.

POWER SUPPLY.

It is now common practice to use rectified alternating current as a source of power for operating the oscillating power tubes which supply the h.f. carrier current to the line. Frequencies as low as twenty-five cycles are successfully employed.

By the use of smoothing inductances and condensers, all trace of A.C. "hum" is eliminated. By the use of such a power unit instead of a motor generator, the guided-wave apparatus can be arranged to respond instantly to remote control. Switching and articulation with local physical telephone circuit is thus greatly facilitated.

USES AND ADVANTAGES.

In the foregoing discussion we have endeavored to point out the limitations of the h.f. multiplex system of telephony, and, incidentally, certain advantages.

In dealing more specifically with the advantages, it is to be noted that, in general, guided-wave transmission gives a more nearly perfect reproduction of the voice than does wire telephony.

In ordinary telephony there are three inherent causes of distortion, *viz.,* the microphone, the telephone receiver, and that due to the line. The first two are, of course, present in the h.f. system. The distortion due to the line is, however, absent. This is evident from the following considerations.

Since the quality or timbre of vocal sounds is due to the presence of overtones, the varying line current in ordinary wire transmission will also have a corresponding complex wave form. In short, when analyzed, this telephonic line current consists of several elemental constituent parts, each component having a different frequency. Since, under a non-resonant condition, attenuation is a function of the frequency, the components of the line current corresponding to the overtones in the voice will suffer different degrees of attenuation, with the result that the wave form will be modified. In ordinary words tonal quality is not faithfully transmitted.

If, in comparison with the process just outlined, it is recalled that in g-w. transmission a h.f. alternating current of a single frequency serves as a carrier wave, and that speech is transmitted by varying the *amplitude* of this carrier wave, it will be apparent that there will be no distortion due to a multiple valued attenuation factor.

There is a possibility that g-w. telephone equipment of such a nature will be designed that the ordinary microphone with its inherent defects will be replaced by a device which will give rise to much less distortion. It is also possible to improve the common telephone receiver in regard to faithfulness of reproduction. If, and when, these improvements are brought about, we will have in g-w. telephony a means of communication whereby practically perfect transmission of the voice may be had. But even under existing limitations the faithfulness of voice production in g-w. transmission, particularly when connection is not made to local land lines, is one of the distinguishing characteristics of this method of communication.

Another important aspect of communication is secrecy. When used as a direct private line of telephonic communication, as in the case of leased lines between business houses in different cities or for press work, we have in this method a system of communication which affords a high degree of secrecy. Common experience indicates how little real privacy obtains when employing the ordinary telephone. While radio telephony has a distinct and very important field in communication at sea, it obviously has serious limitations when employed for strictly personal and business purposes. While there is no known means of communication which cannot be "tapped," yet from the nature of the system, direct guided-wave telephony possesses the greatest element of secrecy of any telephonic means of communication. When, however, the h.f. super-channel is used as a trunk line and connected at either or both ends with local physical telephone circuits, the element of secrecy is no greater than when employing a physical circuit for the entire distance.

Another advantage of the guided-wave system is that communication may be maintained between two points when the physical circuit which serves as a guide for the h.f. waves is out of commission for ordinary telephone service. Both wires of the physical pair may be cut, the line short circuited and at least one of the wires grounded without interrupting communication over the super-channel. This has been repeatedly demonstrated and naturally means much in emergency service of all kinds.

Another feature to be noted in connection with guided-wave telephony is the flexibility of the system. When used as a through trunk channel, a given set of equipment may, as previously indicated, be instantly shifted from one physical circuit to another.

Further, the entire terminal g-w. equipment may be quickly transported from one point on a physical system to another, thus making it possible to readily increase the traffic-carrying capacity of the lines between points where a temporary congestion exists, due to seasonal or other causes.

An added element of flexibility arises from the fact that various sections of physical circuits may be tied together to establish a through super-channel for trunk operation. For instance, several physical circuits may radiate from an intermediate point. Two physical circuits centering at this point may, by suitable means, be connected for the purpose of setting up a through g-w. channel, and at the same time the two physical lines may be connected to any of the other lines centering at the point in question. In other words, the tying together of the lines for g-w. working in no way limits the flexibility of the physical lines for regular telephonic operation.

An important possible application of telephony by guided waves is that of train dispatching. Reference has already been made to the fact that energy is radiated from a physical line which serves as a guide for h.f. carrier currents. Though the amount of energy thus radiated is not great, it has been shown by practical tests that it is sufficient to make possible the establishment of telephonic communication between a moving train and the fixed stations connected to one of the physical circuits paralleling the track.

This is accomplished by installing on the train a radio-telephone equipment connected to a suitable antenna system placed at the top of a car or cars. When the two systems are properly adjusted there will be a mutual interchange of energy between the train's antenna and the physical telegraph or telephone circuit which is conveying the h.f. carrier current from a fixed station. The train equipment may be located in the baggage car with leads extending to the engine cab. The engineer could be equipped with a standard anti-noise transmitter and a receiver helmet similar to that used for radio telephony on aeroplanes. So equipped, the engineer of a train could be in continuous and reliable communication with the train dispatcher. The utility of such a system in train dispatching is obvious.

Another possible application of a similar nature to the above would be the dispatching of electric railway traffic by this type of telephony. Small low power guided-wave sets could be installed on interurban cars and the trolley wire utilized for the purpose of guiding the carrier waves to and from central fixed points. The power supply used for operating the cars is usually of such a nature that it could also be directly utilized for operating the telephone apparatus. The conductor would thus be enabled to speak directly from the car to the operating official at the central office. The necessity for installing and maintaining an independent telephone circuit for dispatching purposes would thus be obviated.

Thus, there are several important special fields for the practical application of this comparatively new means of communication.

It is, however, as private leased lines and for long trunk circuits that guided-wave telephony will probably find its greatest field of usefulness. As already indicated, ordinary local subscribers' telephones may be connected through the usual central switchboard to the high frequency apparatus, the switching being accomplished in substantially the same manner as when connecting to any physical toll circuit. In this manner, the guided-wave system is being commercially used to give additional channels for the handling of "long-haul" traffic.

Although independent guided-wave terminal equipment must be installed for each super-channel that is established, yet the initial and maintenance cost of additional physical circuits is substantially greater than the corresponding cost for the high frequency installation. In general, the financial saving increases as the length of the line increases.

In this discussion we have confined ourselves to guided-wave telephony. There is, of course, a corresponding field in connection with telegraphy. Multiplex telegraphy by means of guided waves is already a commercial fact. We hope in a subsequent paper to deal with the telegraphic aspects of the case.

In conclusion, it may be said that we have in guided-wave multiplex telephony and telegraphy a distinct branch of communication engineering—a new art—which is to command the ability of the most able minds in both pure and applied science. And who shall say whither it will lead?

Analysis of Samples of Ancient Armor. (*Chem. and Met. Eng.,* November 17, 1920, p. 975.)—The analysis and microscopical examination of about one dozen samples of ancient armor from the Metropolitan Museum of Arts, New York, have been practically completed by the Bureau of Standards. The analysis indicates that all the samples were made from very pure wrought iron converted into steel by the old cementation process, as would be expected.

The carbon determination was made on the entire cross-section, as the material of all the pieces was too thin and corroded to obtain samples from different layers.

The microstructure indicates that the process used in the production of the original iron was very similar to our wrought-iron process. The metal was then carbonized, probably by a supplementary process, hammered into sheets, differing in hardness—*i.e.*, in the amount of carburization—and these sheets were welded together.

The whole was then hammered into shape and quenched, thus producing the final hardening effect.

Dyeing of Artificial Silk.—A research on the dyeing of artificial silk, manufactured by the viscose process, has been made by LEONARD PHILIP WILSON and MARJORIE IMISON (*Journal of the Society of Chemical Industry,* 1920, xxxix, Transactions, 322–324). All direct cotton colors cannot be used with artificial silk, since many of these dyes are extremely sensitive to the small differences of dyeing affinity which characterize such silk. Evenness in dyeing at the usual temperature (50° C.) varies with the molecular weight of the dye, and apparently is not influenced by the nature and arrangement of the groups of atoms which constitute the molecule of the dye. Thus Rosophenine 10 B (molecular weight 600) and Indoine Blue (molecular weight approximately 521) dye evenly, while Dianol Fast Pink B. K. (molecular weight 944) and Dianol Sky Blue (molecular weight 992) dye very unevenly, and Diamine Green B (molecular weight 812) dyes fairly unevenly. Hence a fabric of artificial silk may show variations in shade if dyed with colors of high molecular weight, and will be of practically uniform shade if dyed with colors of low molecular weight. If the temperature of the dye bath be elevated, say to 75° C., and the silk then be introduced, more even dyeing is obtained. A mixture of even and uneven colors in a dye bath almost always yields worse results than are obtained with uneven dyes alone. Deficiencies in the direct colors may, at times, be overcome by use of sulphur dyes. Basic colors produce extremely bright shades and even dyeing on artificial silk; if a mordant be used, the most even results are obtained by dyeing in a neutral bath, then fixing in tannin and tartar emetic.

J. S. H.

A Photographic Method of Finding the Instantaneous Velocity of Spark Waves. A. L. FOLEY. (*Phys. Rev.*, November, 1920.)—On the assumption that the displacements concerned in a sound wave are infinitely small, Newton derived an equation for the velocity of sound which gave the same velocity for all sounds. From the experiments of Regnault it has been known that loud sounds travel faster than faint ones. This difference has been the subject of much consideration, both theoretical and experimental.

At about the middle of a long, narrow box two terminals were placed between which passed the spark producing the sound. Its axis was parallel to the length of the box. At one end of the box was rotated a steel disk on whose edge were notches irregularly spaced and of different depth to furnish individuality for identification. The sound spark projected the shadow of the notches on a photographic plate placed close to the disk and with its plane parallel to that of the latter. A little after the sound spark had jumped a second spark, the illuminating spark, was produced at the end of the box distant from the steel disk. During the interval between the two sparks the sound wave from the first spreads out. Its shadow in the light of the second spark is projected on the plate and is photographed. The disk, too, has been rotating and the shadow of its notches are photographed again. The two impressions due to the same notch will not coincide, not only because the disk has rotated, but also because the source of the light in the two projections is different. From the dimensions of the apparatus, the speed of the disk and the location of the two photographs of the same notch, it is possible to calculate the interval in seconds between the production of the two sparks. From the radius of the shadow of the sound spark the distance the sound travelled in the interval between the two sparks can be found. From these data the velocity of the wave is derived. The illuminating spark could be made to appear at varying intervals after the sound spark, and thus the sound was given different lengths of time in which to expand before it was photographed.

When the wave had proceded 3.2 mm. from its origin the velocity was found to be 678.6 m. per second—almost twice that of normal sound waves. This became rapidly less as the wave spread out, becoming nearly normal at 20 mm. from the source. The velocity of the wave increases when the intensity is increased, whether this be accomplished by changing the spark or by merely examining the wave closer to its source.

The comparison of the photographs of two parts of the same wave, one of which travelled in free air while the other passed through a tube, showed that the latter outran the former and, in fact, had a velocity about 22 per cent. greater.

The methods employed by Professor Foley are elegant and make an appeal to the esthetic as well as to the scientific judgment.

G. F. S.

THE MODERN CARGO VESSEL.*

BY

WILLIAM GATEWOOD.

Newport News Shipbuilding and Dry Dock Company, Newport News, Va.

THE cargo vessel has proved of inestimable value to mankind from the days of Noah, when the "Ark," the first "cattle" ship of which we have a record, saved the people of Western Asia, from starvation and from death from exposure, to the present century, when the modern cargo vessel has saved the people of Western Europe from as dreadful a fate. Civilization is made possible by commerce, and as commerce cannot thrive without suitable means of carriage, the humble cargo vessel is the handmaid of progress.

The cargo vessel, like so many other live institutions, has been an evolution, and the type of vessel has adapted itself to the needs of its day and generation. The primitive type was a raft, without means of locomotion, and with a pole for steering. This was probably succeeded by the canoe, with pole for pushing as well as for steering, and later with paddles replacing the pole. As the necessity arose for larger vessels, the oar replaced the paddle. Man does not care to burden his life with any labor which can be avoided, and some lazy man, as like as not, discovered that the wind would relieve him of exertion if he would rig up a sail. So sailboats became common, and the rowing galleys were manned only by convicts condemned to hard labor for life.

In order to appreciate the real value of the modern cargo vessel, and its adaptability to the needs of the twentieth century, it will be advisable to note the status of self-propelled vessels at various epochs. It will not be necessary to go further back than the discovery of America, as that marks the real beginning of ocean transportation. The flagship of Columbus is stated to have been a vessel about 100 feet long and its gross tonnage, according to present measurement, was about 250 tons. The records indicate an average speed of only four knots on the voyage to this side of the Atlantic, although the wind was favorable most of the time.

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* Presented at a meeting of the Mechanical and Engineering Section held Thursday, January 13, 1921.

The size of vessels increased considerably during the century immediately following the discovery of America, and the Spanish, in particular, carried on considerable trade between the Philippines and Panama and thence to Spain. The English vessel of this date was still quite small, as the largest of the vessels which landed the first colonists in Virginia in 1607 was only about 80 ft. long.

The advent of the marine steam engine in 1807, or thereabouts, marks one advance without which the modern cargo vessel could not have been developed. For many years steam power was applied through paddle wheels, and seagoing wooden paddle steamers were in use for transatlantic travel from 1819, when the American steamship *Savannah* made her maiden voyage, until after the Civil War.

FIG. 1.

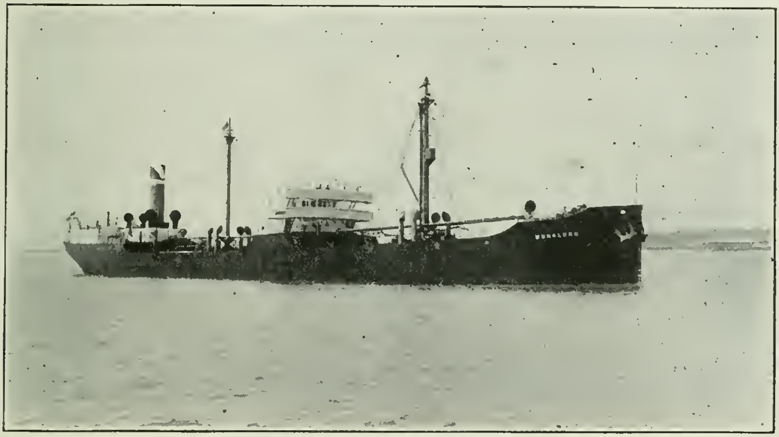
Atlantic liners, seventeenth century.

Two other essential developments were made during the nineteenth century. The screw propeller was perfected so as to be commercial, the first use on a merchant vessel of which I have been able to find a record having been in 1838 on the *Robert F. Stockton.* In 1841 only three English merchant vessels had been fitted with screw propellers. This type of propeller removed the primary disadvantage of steam propulsion, and its later development definitely relegated the sailing vessel to a minor position in the world's commerce.

The application of iron and steel to ship construction was the other development which has made the modern cargo vessel possible. The first iron steamboat was the *Aaron Manby,* built in

1820, for service between London and Paris. The first iron vessel to cross the Atlantic is stated to have been the first screw steamer previously mentioned, the *Robert F. Stockton.* Many of the early iron vessels were small, but the possibilities of iron in ship construction were foreshadowed in the *Great Eastern,* 680 feet long, which was begun in 1854 and completed in 1859. No other vessel of that date exceeded 400 feet in length, so that a large step forward was made at that time in the size of vessels. While the *Great Eastern* accomplished a useful work, particularly in laying the first submarine cable, it was too large for the commerce of its day, and could not be considered a commercial success. I find a record in a notebook of my father, who was then living in Norfolk, Va., under date of August 4, 1860, which reads: "To see the *Great Eastern*—$2.00."

FIG. 2.



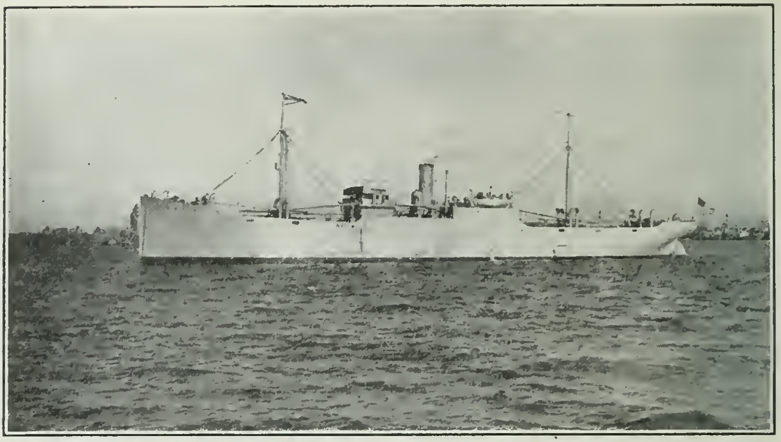
For coal or bulk freight. Gross tonnage, 4300.

Mild steel was introduced in about 1876, and the modern cargo vessel is possible only on account of the development of the steel industry, in which the State of Pennsylvania has played no mean part.

The modern cargo vessel is built of mild steel, is propelled by a screw propeller operated generally by steam machinery, is steered with a rudder operated by steam and controlled from the bridge, is navigated by magnetic compass, has its location determined by chronometer and sextant, and has its cargo handled by block and tackle from booms on masts or derrick posts by means of steam winches. The size, arrangement, speed and fuel are specialized to suit the exact requirements of the trade, and few trades call for exactly the same design.

The cargo vessel of the future may be built of high tensile or special steel, but there are no indications at present that mild steel will be superseded in the near future, except on the largest vessels. It may have some other kind of propulsion than by a screw propeller, but there are no indications of any more efficient method, although some improvements may be made in the type of screw. The reciprocating steam engine is being superseded by the geared turbine, and the turbine is being used also in conjunction with electric generator and motor, instead of gears. The water tube boiler for generating steam is now becoming almost as well known as the cylindrical boiler, and the majority of new vessels use oil as fuel instead of coal. The internal combustion Diesel engine is being developed and used, and it is possible that this will be the prime mover of the future on account of its economy, unless oil becomes too expensive to be used at all. Electric motors are well suited for operating any type of steering gear, including hydraulic, and when steam is not used for propulsion, electric auxiliaries are the natural arrangement. The gyro-compass may

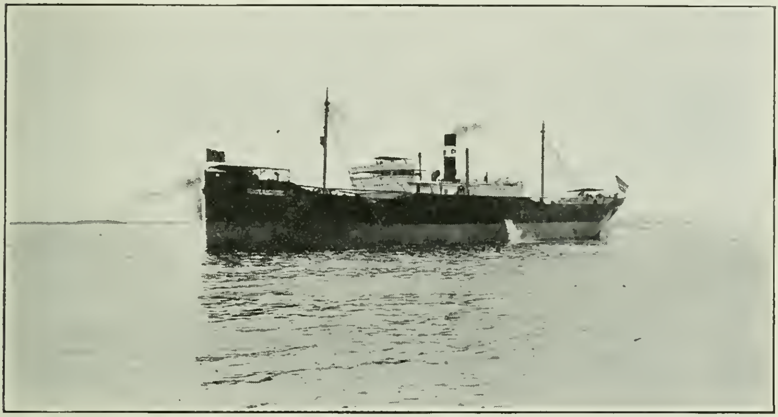
FIG. 3.



A cargo vessel of 7500 tons deadweight.

replace the magnetic compass, as the gyro-compass is now used on Atlantic liners and in the navy. The variation of the magnetic compass, first discovered by Columbus, is still a source of confusion, and the deviation of the compass due to the ship's magnetism is a continual cause of anxiety to the navigators. No substitutes for the chronometer and sextant are being experimented with, so far as I know, but the "wireless" is already being used to give the location near the coast in a fog, and to check the time. Electric winches are common on naval vessels and are used also when internal combustion engines constitute the propelling mechanism.

FIG. 4.

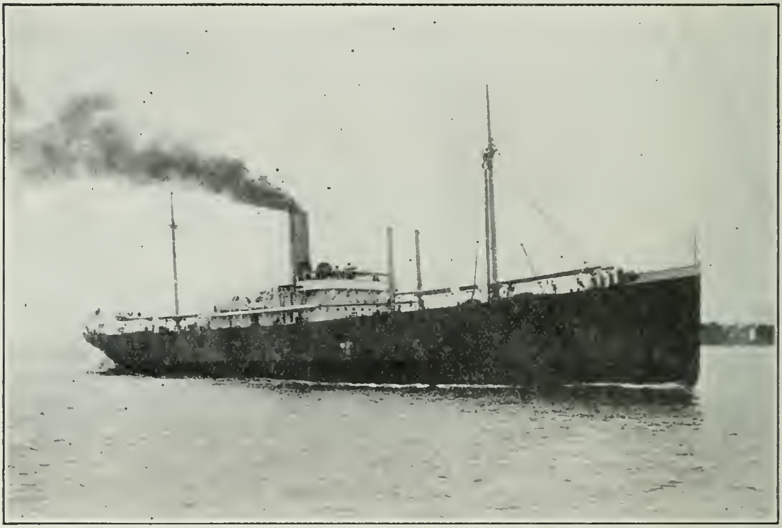


A cargo vessel of 9600 tons deadweight.

Reinforced concrete is being used in the construction of cargo vessels to a limited extent. The aggregate used weighs much less than that used in land construction, so that the concrete vessel is not so very much heavier than the steel vessel. Concrete, however, is liable to develop cracks under tensile stress, and the sides seem to be susceptible to damage in docking. It does not seem likely to be much used for ship construction in the future. In a well-designed steel vessel of large size, almost all of the steel is required to withstand tensile stress, and so no reduction in the amount of steel used for reinforcement could be made, as the concrete is of value only in compression. The weight of the concrete must be almost entirely in excess, therefore; and the reduction in cost of construction, if any, can hardly be great enough to offset the loss in deadweight.

The size of a cargo vessel is made to suit the length of voyage and the amount of cargo available. There is no economy in having a large vessel in a given trade unless the vessel can be fully loaded on most of her trips. The commercial life of a vessel may be taken as twenty years, and a depreciation of at least 5 per cent. per annum on the investment should be allowed as a part of the cost of operation. Not less than 5 per cent. interest on the investment should be gained in addition, and repairs will amount to an average of not less than say 2 per cent. of the first cost, so that not less than 12 per cent. of the first cost must be carried each year in addition to the cost of operation. The first cost, therefore, is of prime importance in determining the particulars of a vessel. Other things being equal, the cost increases with the size, and therefore the vessel should not be larger than the amount of cargo justifies.

FIG. 5.

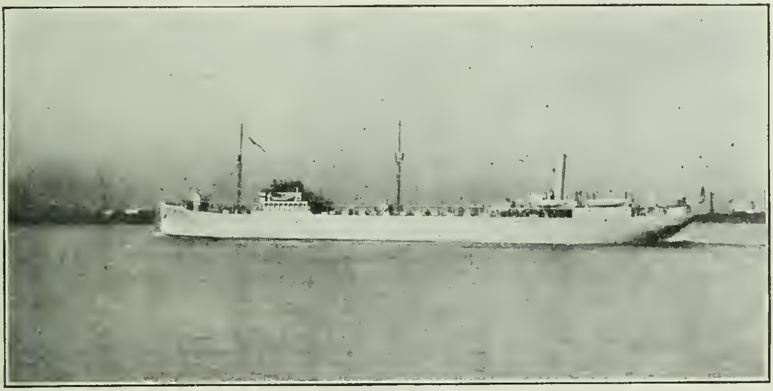


A shelter deck liner, 14 knots speed.

The economy in operation resulting from increase in size, however, is very great. It takes very few more in the crew to man a vessel of 10,000 tons than to man a vessel of 5000 tons, as the same number of licensed officers are required on each vessel and only about six additional men are needed in the crew. The horsepower required for the same speed is increased in the larger vessel by only about 50 per cent., and the machinery may be made somewhat more economical so that the fuel consumption will be increased by less than 50 per cent. If the operating costs of crew, fuel and supplies amount in the course of a year to 30 per cent. of the first cost in the case of the smaller vessel, they would amount to only about 24 per cent. in the case of the larger vessel.

The larger vessel would carry about two and a quarter times as much cargo in the course of a year, as the machinery and fuel would occupy proportionately less space and weigh proportionately less, and the number of voyages need not be less, as the slight increase in the time in port, if any at all, would be counterbalanced by the less interference with regularity of speed on account of bad weather.

FIG. 6.



Tanker, shelter deck type.

The first cost of the larger vessel would be considerably less than double that of the smaller vessel, on account of the fact that the weight and cost of the hull and fittings is not twice as great and the cost of the machinery would be only about one and a half times as much. The first cost may be taken as about 1.8 times as great.

The advantage of doubling the size of a vessel, then, may be summarized as follows:

The carrying capacity of the larger vessel will be about 2¼ times as great.

The operating cost of the larger vessel will be about 36 per cent. of its first cost when the operating cost of the smaller vessel is 42 per cent. of its first cost.

The first cost of the larger vessel will be about 1.8 times the first cost of the smaller vessel.

The comparative cost of operation of the larger vessel per ton of cargo will be only about three-quarters as much as the similar cost for the smaller vessel.

FIG. 7.

For passengers and package freight. Troops during the war.

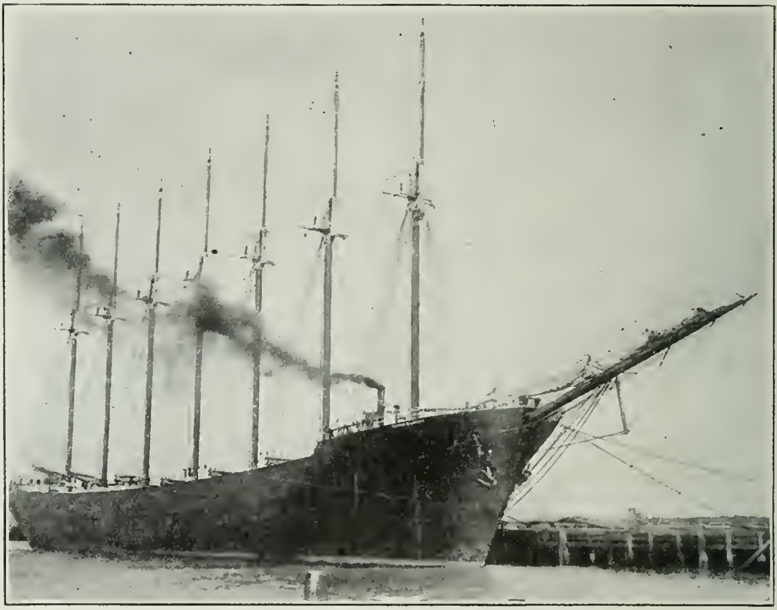
The natural thought would be that by increasing the speed of a vessel quite an advantage would be gained. Such is seldom the case, however. If a vessel, for instance, has a speed of 9 knots and spends two weeks at sea to one in port, the first cost of a vessel to carry the same weight of cargo each trip would be nearly double for an increase in speed of 50 per cent., and the cost of operation would be at least double, while the faster vessel would carry only 30 per cent. more cargo in the course of a year. It is this economic fact which keeps the average speed of cargo vessels so nearly the same as it was twenty years ago. The tendency in this country, however, is to build for a speed of between 10 and 12 knots, and few vessels are being built of less speed than 10 knots. The effect of bad weather is much greater on the slower speed vessels, and the increased length of time the cargo is in transit operates to reduce the freight rates. It is generally conceded that only vessels for carrying passengers and express freight should be designed for speeds in excess of 16 knots, and quite a number of passenger vessels are running at a speed of about 14 knots. The larger the vessel the less the economic disadvantage in the higher speed, as the power required for the same speed does not increase directly as the size of the vessel but only as about the two-thirds power of the displacement, and a somewhat higher speed can be obtained without using as great a proportion of the displacement for machinery and fuel.

FIG. 8.

In pace decus, in bello praesidium.

The underwater form of a vessel may be made quite bluff if a low speed is deemed sufficient, but the lines must be made finer as a higher speed is sought. The block coefficient is the term used to denote the proportion which the volume of the vessel under water bears to the circumscribed parallelopiped. For a speed of 10 knots the block coefficient is about 80 per cent. in a vessel 400 ft. long, and may be increased to 82 per cent. in longer vessels, while it would be reduced to 78 per cent. in a vessel 350 ft. long. It ranges between 78 and 82 per cent. in the ordinary cargo vessels. As the speed increases, the block coefficient is reduced, and in some recent freight and passenger vessels 518 feet long and designed for a speed of 16–17 knots, it was made as small as 65 per cent.

Fig. 9.

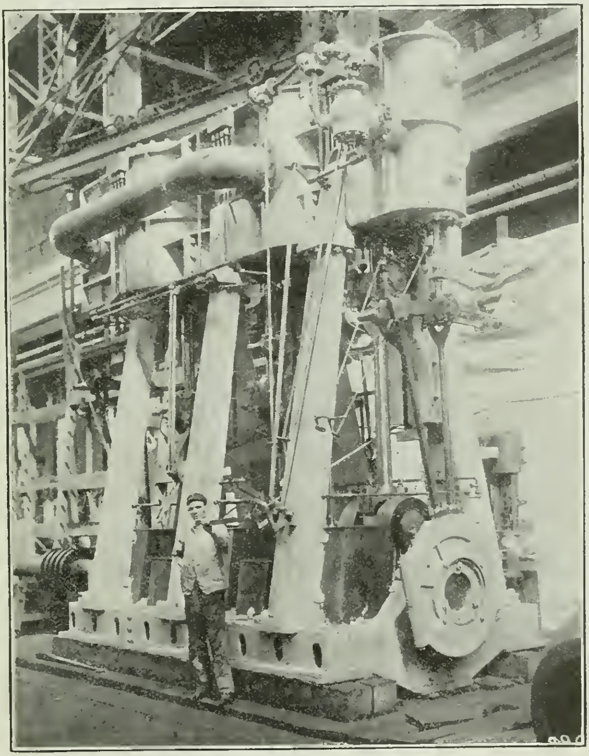


Seven-masted steel schooner.

The high cost of construction of the hull, and the broken stowage, however, do not recommend such a fine block even though a higher speed is obtained for the same power. Bad weather reduces appreciably the speed of a very fine vessel, causing heavy pitching, so that a vessel should be neither too bluff nor too fine. The present tendency on cargo vessels is toward a fining of the bluff bows which were so common earlier in the century, and also toward fining the stern, not only to preserve the trim, but also to give a better flow of water to the propeller and to gain in efficiency of propulsion thereby.

The above water form of hull of modern cargo vessels provides usually a flaring bow in order to prevent the waves from breaking over the deck, a smooth sheer line with about twice the rise forward as aft, with erections to suit the needs of the service. In most of the fabricated vessels there is no sheer at all, but such vessels are not as good sea boats, and under the present rules for determining freeboard they cannot load as deeply. Many vessels have been built in this country with a straight sheer for the half length or more amidships and with a quick sheer forward and the usual amount of sheer aft. This practice simplifies the construction, increases the strength somewhat, and does not offend the average

FIG. 10.



Triple expansion engine, 1200 I. H.-P.

eye. It will probably come into more general use, especially when the rules for determining freeboard are made rational instead of empirical.

Vessels with forecastle, bridge and poop are still the most common, although the shelter deck type is coming more into favor. The latter provides more cubic space for the same weight of cargo, and is better adapted for general cargo on that account.

The submarine is not likely to be a competitor with surface vessels in the carrying of cargo, as all the troubles of surface vessels are magnified greatly when the complications of running submerged are added.

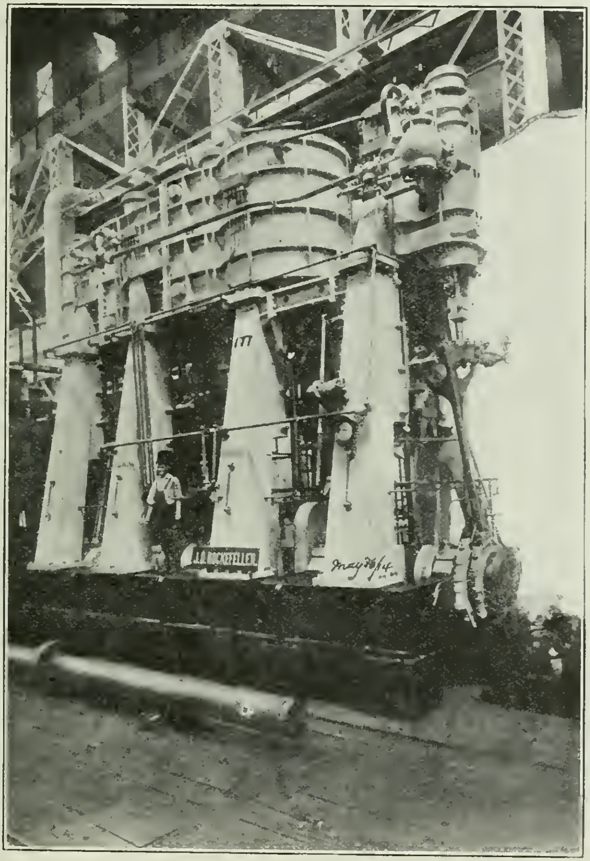
Cargo vessels may be divided into two general classes—liners and tramps. The former are like business men who travel between home and office with an occasional stop off at the club for lunch. The name of the latter is a misnomer as they do not correspond to tramps at all, but more nearly to the harvest hands who work wherever they can find work to do.

If a vessel is not always sure of a return cargo, and has no means provided for a large amount of water ballast, the machinery is usually placed amidships. This is the common type. In oil tankers, colliers, and a few liners, including some vessels carrying passengers, the machinery is located aft, and this type of vessel is becoming quite numerous. The midship portion of the vessel is the best for carrying cargo, while the machinery fits very nicely in the stern, and the troublesome shaft alleys are avoided.

The type of steam engine installed on most cargo vessels is the inverted vertical three-cylinder triple-expansion reciprocating engine. This type has been in use for about forty years, the first successful one having been installed in 1881 in the *Aberdeen*. It has been improved in details, and the ratio of expansion has been increased as the boiler pressure was raised, but it is essentially the same machine, and engineers have become so accustomed to it that a breakdown in service is almost unknown. A number of four-cylinder triples are in service, and the four-cylinder quadruple engine is quite common in liners, and very economical.

The geared turbine was introduced in cargo vessels in 1910 by Sir Charles Parsons on the *Vespasian*, as the only method of using steam turbines on slow speed vessels with any economy. The modern gears are not of the same type as were used sixty years ago in the *Great Eastern*, for instance, but are of steel cut with the minutest accuracy. A high speed of revolution is necessary in order that a steam turbine shall function with economy in the use of steam, while a slow speed of revolution is necessary in order that the propeller shall be efficient. A gear ratio of 15 to 1 is about the average for a single reduction, while a ratio of between 30 and 40 to 1 is used with double reduction gears. Both the Curtis and Parsons type of turbines are in common use, but neither have displaced the reciprocating engine as yet. So many are now in use that the reliability of both the turbines and gears will be determined shortly, and as they weigh less, take less

FIG. 11.



Quadruple expansion engine of 2800 I. H.-P.

room and have possibilities of economy greater than the reciprocating engine, they seem sure of an extended use in the future.

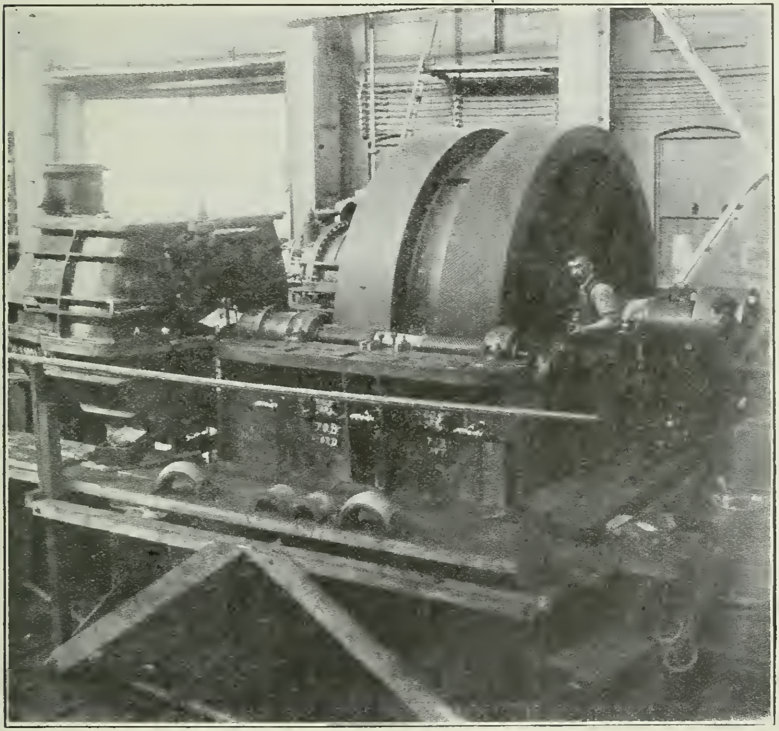
Electric propulsion was introduced on the Navy collier *Jupiter* in 1913 by the General Electric Company, and has recently been fitted on merchant vessels. In this system of propulsion an electric generator is driven by a high-speed turbine, and the propeller is operated at a suitable speed by a motor. The steam consumption is very moderate, and some eminent marine engineers in this country consider that the electric drive is one of the coming forms of propulsion for cargo and passenger vessels. It is slightly heavier than the reciprocating engine and much heavier than the geared drive, and probably will prove more expensive to build, so that its future use will depend on how well it can overcome these handicaps in the course of its development.

The internal combustion oil engine for marine use was introduced in Italy in 1910. It has been developed up to units of slightly over 2000 horsepower, and its consumption of fuel oil is reported to be only half as much as in the best form of steam machinery. In its present state of development, it is considerably heavier than steam machinery of the same power. The earlier installations have not always proved reliable, but as experience has been gained in its design, construction and operation it has given greater satisfaction in service. At present, its first cost is considerably in excess of steam machinery, and the power of a single unit is limited, so that it offers no immediate advantage financially except on long voyages on which the saving in the fuel supply needed will enable a heavier cargo to be carried. A recent American installation is that on the *Cubore,* which came out in the summer of 1920.

The use of steam machinery for marine purposes was handicapped until the cylindrical multitubular boiler, commonly called the "Scotch" boiler, was developed in about 1862. As the steel mills became able to roll larger and thicker sheets, this type of boiler increased in size and ability to carry heavier steam pressure, so that one single-ended four-furnace boiler 17 ft. in diameter can now be built to generate steam at 200 lbs. per square inch, sufficient for an indicated horsepower of 1200 or more, although three-furnace boilers for a working pressure of 160 to 180 lbs. are the common size. This type of boiler can be used to burn either coal or oil, and like the reciprocating engine, it is so well known that a breakdown in service is rare, although repairs on account of carelessness are not as infrequent as they should be.

The water-tube boiler was introduced in the merchant service about twenty-five years ago, and has been used quite extensively recently, especially in connection with oil as fuel. It is considerably lighter than the Scotch boiler, but, on account of the small amount of water contained, it requires more care in operation. The Scotch boiler has nothing to recommend it theoretically, but its reliability keeps it in use, and like the reciprocating engine it is likely to be installed in cargo vessels for many years yet.

FIG. 12.



Geared turbine, 6000 S. H.-P.

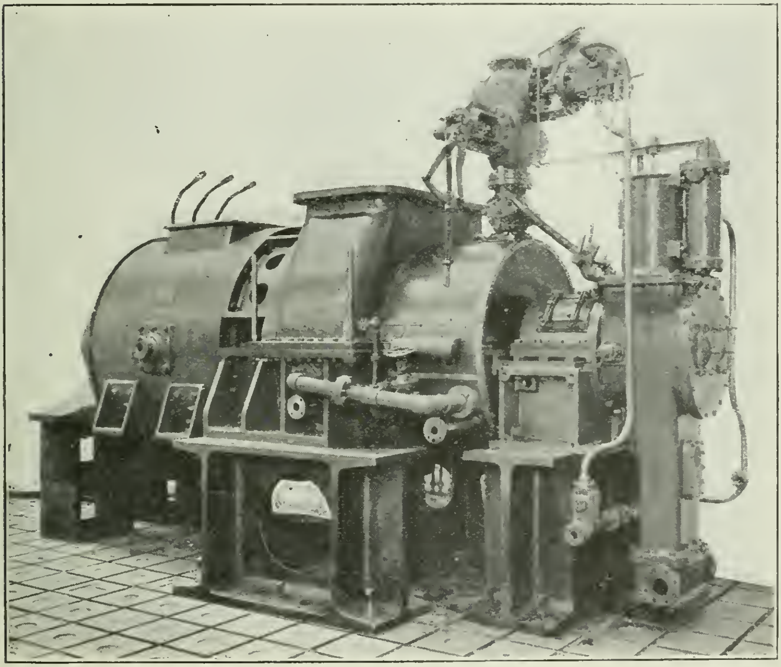
The fuel used in cargo vessels until quite recently was bituminous coal. Anthracite coal was discarded after a few years of use, as it was found to be more difficult to adapt to the varied requirements of service. Many cargo vessels do not have artificial draft, but quite a number of coal burners are fitted with heated forced draft, introduced by James Howden in 1884. Since the advent of fuel oil, its use on board ship has been extended so that very few vessels of the present day are designed for coal burning, although the greater number of the vessels afloat still burn coal. The tramp and the liner are both dependent on fueling stations. Very few vessels carry enough fuel for a round trip, and some of the routes are so long that fuel must be taken on at an intermediate station. The United States has about twenty-one commercial fueling stations at which oil can be obtained, in addition to its home ports. England has numerous coaling stations scattered over the world, but fuel oil is not obtainable except at a comparatively few ports, so that tramp steamers cannot use oil with satisfaction. At first, steam was used to atomize the oil, but that method was found unsatisfactory on account of the waste of fresh water involved, and at present the oil is heated to vaporizing temperature and sprayed mechanically. Heated forced draft is used to burn the sprayed oil, in most cases, and very satisfactory economy is obtained.

Ships are built to stay at sea in stormy weather, and their structure must be strong enough to withstand wind and wave. In the days of the wooden ship, the effect of storms was shown first in the working of the seams, and pumping had to be resorted to regularly to keep down the leaks. In steel ships, the strength of the bottom of the vessel is usually greater than that of the deck, and the riveted seams do not leak so easily, so that except in old vessels a defect of strength was indicated by the posting of the vessel as missing. The stresses in a vessel are greatly increased if the vessel is overloaded, but the effect of overloading is not felt except in a storm. It was some time before this fact was properly appreciated, and a limit to the loading was found to be necessary.

In Great Britain, Mr. Samuel Plimsoll took the matter up in 1875, and an Act of Parliament was passed requiring a mark to be located amidships on each side deeper than which a foreign-going vessel should not be loaded. This mark is known as the " Plimsoll " mark. Its location is determined for British vessels since 1890 by certain rules known as Freeboard Tables based on retaining a certain percentage of buoyancy at the load draft, and assuming that the strength of the vessel was that obtained by using the scantlings required for the vessel by Lloyd's Register of Shipping and set forth in Lloyd's Rules.

In the United States, there is no legal enactment to prevent overloading, although a Committee has been appointed by the Secretary of Commerce to formulate recommendations. A British committee has recently proposed a modification of their freeboard tables basing the loading on an absolute criterion of strength, so that the stronger a vessel the deeper she will be allowed to load. With proper precautions as regards the tightness of hatches and the safety of movement of the crew, this would seem logical. It is hoped that our Government will afford a similar measure of protection to the humble cargo vessel. In the matter of loading, the stresses increase more rapidly as the draft increases, and even a foot of overloading is likely to strain the

FIG. 13.

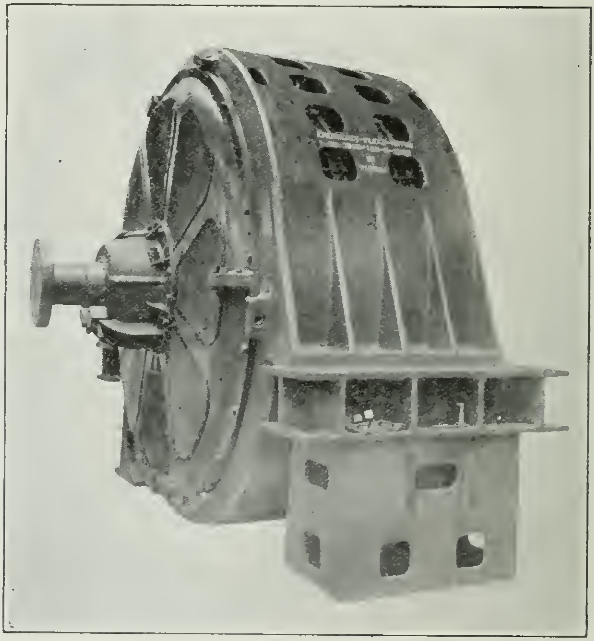


Marine turbine generator, 3000 I. H.-P.

structure in a storm, and if persisted in to cause the loss of the vessel.

The hull of a vessel is essentially a hollow girder. The shell is stiffened by frames, and is subdivided by diaphragms called bulkheads, if vertical, and called inner bottom or decks, if horizontal. The weather deck of steel and iron cargo vessels for a number of years was made of wood, later of iron or steel sheathed with wood, but in general wood decks have been discarded except over the quarters for the crew and passengers. In the early days of iron ships, only bars and plates were rolled, but the advantage of rolled shapes was so apparent that angle and other sections were soon obtainable in a great variety of sizes. In the ordinary cargo vessel about two-thirds of the steel is plates and one-third shapes.

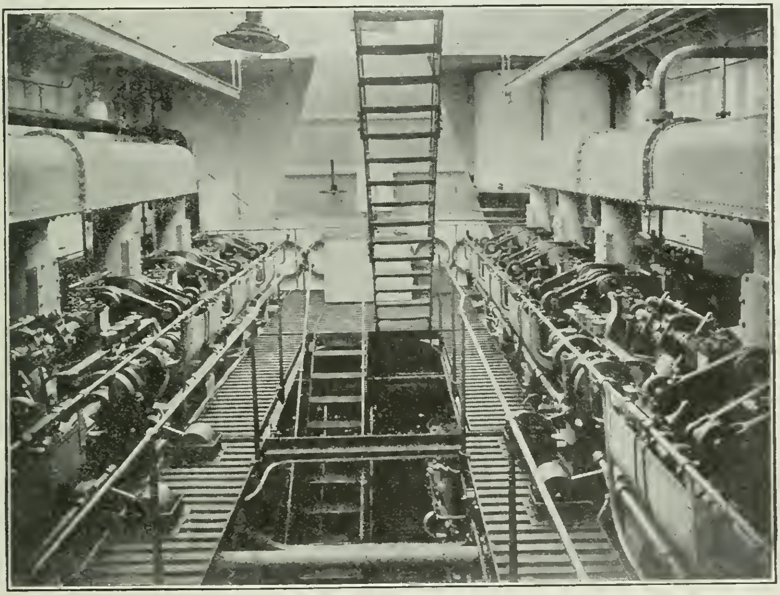
FIG. 14.



Induction motor, 3000 H.-P.

Following the method of framing adopted in wooden vessels, the frames were fitted transverse to the length. This type of framing was the only type which could be used in composite vessels; that is, vessels with metal frames and wood planking. The classification societies prepared rules for the scantlings with transverse framing, and as transverse frames are easily fabricated and erected, this type of framing became the sole type used for many years, and is now used on the majority of cargo vessels, with the exception of tankers. In the middle of the nineteenth century, John Scott Russell developed the longitudinal system of framing, as exemplified in the *Annette*, the *Great Eastern*, and a number of others. In this system, there are a number of widely spaced rigid transverse members which support longitudinal frames by which the shell plating is stiffened. This method of framing went out of use, because channel and bulb angle sections were not rolled at that time, and the cost of fabrication and erection of the plate and angle sections was too great. The advent of the bulk oil carrier, the tanker, showed the necessity for some type of framing better suited than the transverse, and the longitudinal system was re-introduced by Mr. J. W. Isherwood in 1908, using rolled sections for the longitudinal frames and making

FIG. 15.

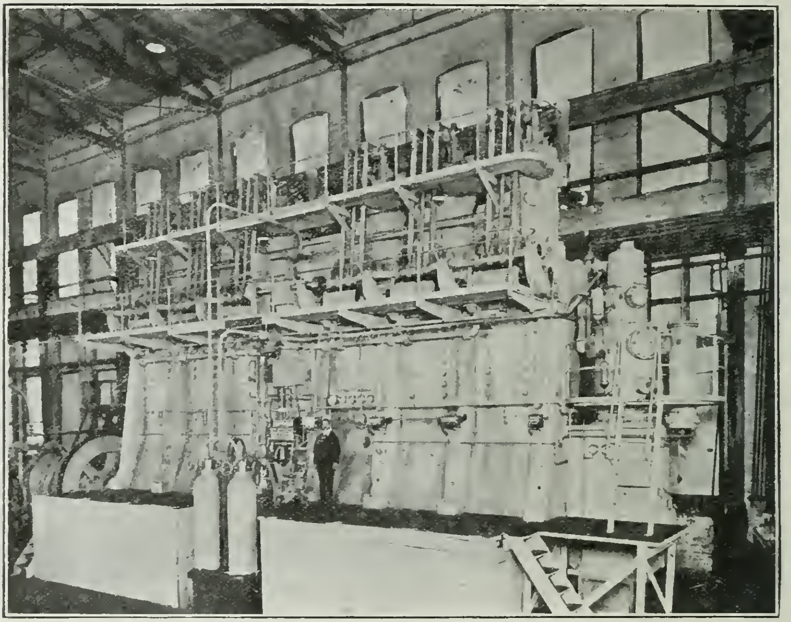


A Dutch installation of Diesel engines.

the transverse members much deeper than the longitudinals so that the latter could fit in slots cut in the edge of the transverses. This type of framing has proved very satisfactory on tankers, greater strength being obtained with less weight of material. It is used with advantage on other types of vessels also, but transverse framing is still the more popular for ordinary freighters.

It is very difficult to calculate the stresses to which the various parts of a ship are subject, so that it was early found necessary to prepare tables and rules giving the scantlings to be used in the construction of the hull and machinery of vessels of ordinary size. These rules were mostly empirical, and a damage on one vessel was often the occasion for penalizing all vessels thereafter built. These rules were issued by classification societies, and if a vessel were built according to the rules it was eligible for classification, and upon payment of a fee it was assigned a class. The classification societies issue register books listing the general particulars of all vessels, including their class or rating, and this

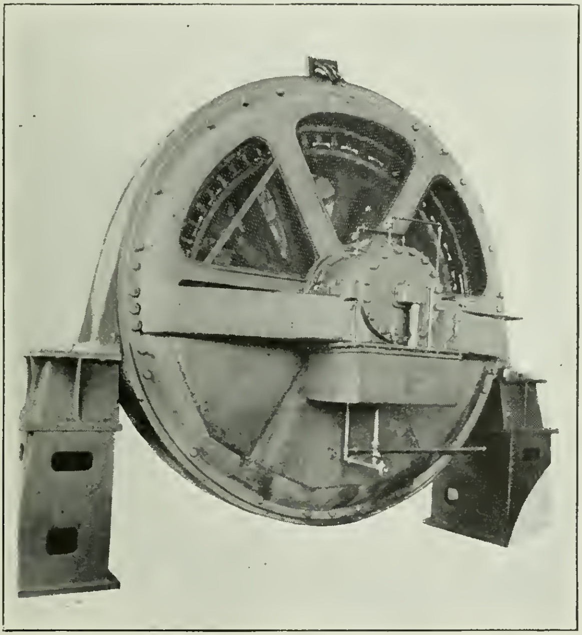
FIG. 16.



A Diesel engine built in America.

rating is accepted by the marine underwriters in fixing the premium for insurance on the vessel and its cargo. To be efficient, a classification society must have surveyors at all the principal ports, as well as at the building yards, so that proper repairs may be required in case of breakdown. Inspection at frequent intervals is required in any case, as deterioration and wear are inevitable, and many so-called accidents are avoided by remedying the defects disclosed by these periodical surveys. The dominant society is Lloyd's Register of Shipping, an English society which is godfather to more cargo vessels of all nationalities than any other. In the United States, the American Bureau of Shipping has been recently strengthened, so that it is no longer necessary to rely on a foreign institution for the classification and survey of vessels under the American flag.

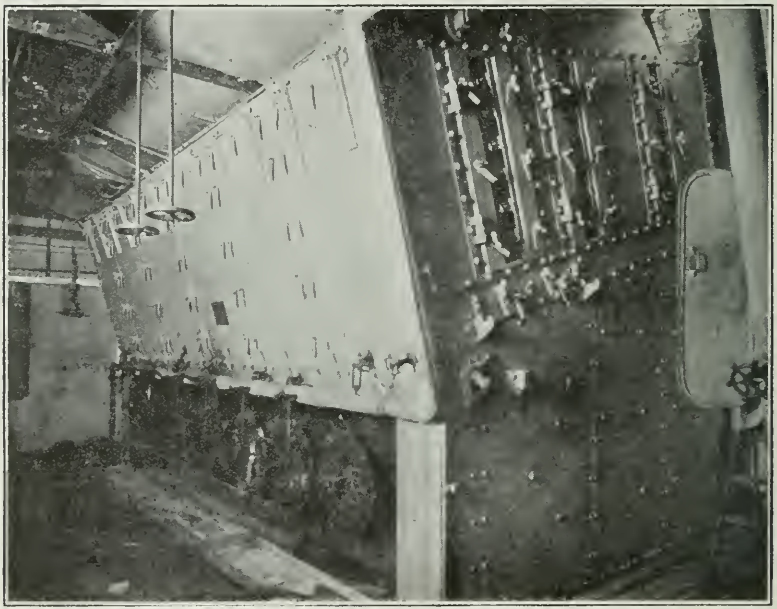
FIG. 17.



Synchronous motor, 3000 H.-P.

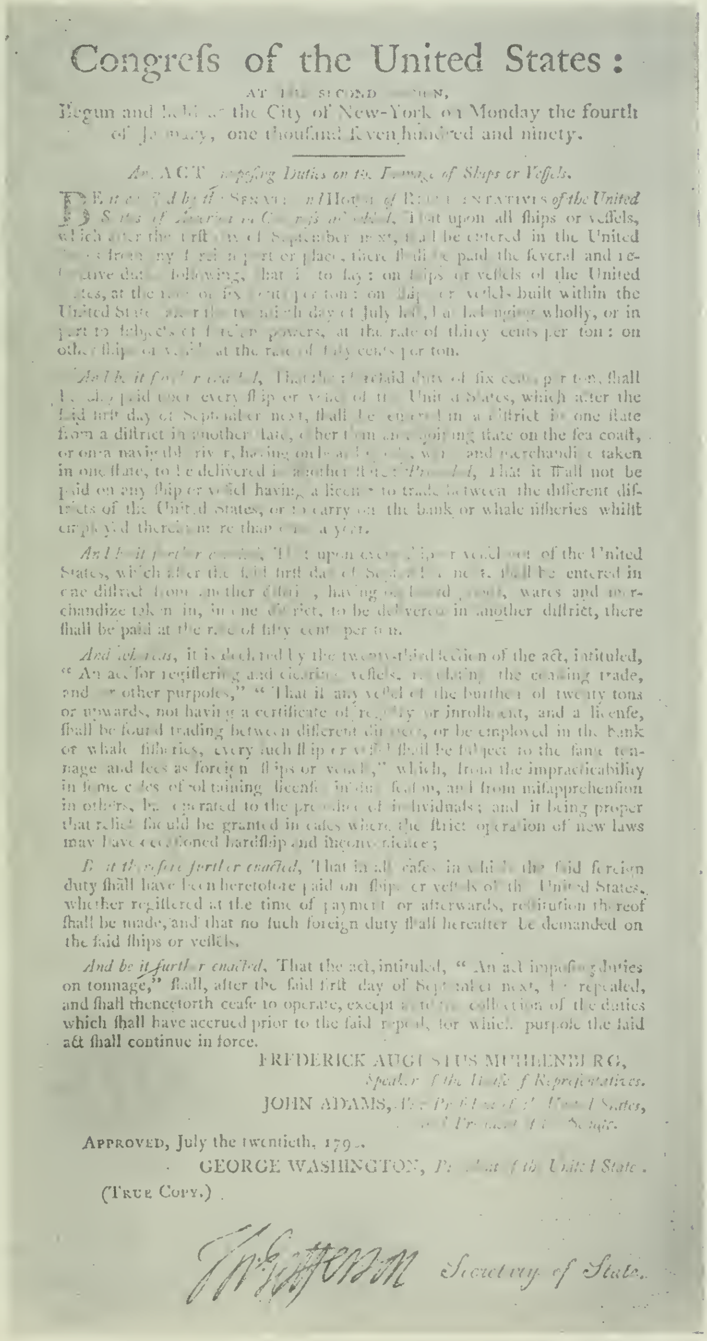
The question of insurance and underwriting is of prime importance, as very few shippers are willing to trust their goods in the cradle of the deep, no matter how staunch the vessel may be in which they are rocked. Even the United States Government requires insurance on everything belonging to it that is not carried on a naval vessel—a procedure which is not warranted by the underlying basis for insurance, as it can well afford to carry its own insurance. Steps are being taken at the present time to extend American underwriting, so that we may be independent of foreign nations in that respect also. This is particularly fitting, as a ship of a country carries its flag and represents its nationality.

FIG. 18.



Oil-burning water-tube boiler.

A cargo vessel considered as a unit may be likened to a beast of burden—seldom good-looking and usually devoid of dignity. It needs a certain amount of care from those in authority, however. It should not be overloaded, else its back will break—and vessel, cargo and crew are likely to be lost. It must not be driven too hard else the boiler will explode, or the shafting break, or the steering gear become deranged—and the sea is not safe for a vessel which is not under control. It should have careful officers,



Congreſs of the United States:

AT THE SECOND SESSION,
Begun and held at the City of New-York on Monday the fourth
of January, one thouſand ſeven hundred and ninety.

An ACT impoſing Duties on the Tonnage of Ships or Veſſels.

BE *it enacted by the* SENATE *and* HOUSE *of* REPRESENTATIVES *of the United States of America in Congreſs aſſembled,* That upon all ſhips or veſſels, which after the firſt day of September next, ſhall be entered in the United States from any foreign port or place, there ſhall be paid the ſeveral and reſpective duties following, that is to ſay: on ſhips or veſſels of the United States, at the rate of ſix cents per ton: on ſhips or veſſels built within the United States after the twentieth day of July laſt, but belonging wholly, or in part to ſubjects of foreign powers, at the rate of thirty cents per ton: on other ſhips or veſſels at the rate of fifty cents per ton.

And be it further enacted, That the aforeſaid duty of ſix cents per ton, ſhall be only paid once every year on ſhips or veſſels of the United States, which after the ſaid firſt day of September next, ſhall be entered in a diſtrict in one ſtate from a diſtrict in another ſtate, other than an adjoining ſtate on the ſea coaſt, or on a navigable river, having on board goods, wares and merchandiſe taken in one ſtate, to be delivered in another ſtate: *Provided,* That it ſhall not be paid on any ſhip or veſſel having a licenſe to trade between the different diſtricts of the United States, or to carry on the bank or whale fiſheries whilſt employed therein, more than once a year.

And be it further enacted, That upon every ſhip or veſſel not of the United States, which after the ſaid firſt day of September next, ſhall be entered in one diſtrict from another diſtrict, having on board goods, wares and merchandize taken in, in one diſtrict, to be delivered in another diſtrict, there ſhall be paid at the rate of fifty cents per ton.

And whereas, it is declared by the twenty-third ſection of the act, intituled, "An act for regiſtering and clearing veſſels, regulating the coaſting trade, and for other purpoſes," "That if any veſſel of the burthen of twenty tons or upwards, not having a certificate of regiſtry or inrollment, and a licenſe, ſhall be found trading between different diſtricts, or be employed in the bank or whale fiſheries, every ſuch ſhip or veſſel ſhall be ſubject to the ſame tonnage and fees as foreign ſhips or veſſels," which, from the impracticability in ſome caſes of obtaining licenſes in due ſeaſon, and from miſapprehenſion in others, has operated to the prejudice of individuals; and it being proper that relief ſhould be granted in caſes where the ſtrict operation of new laws may have occaſioned hardſhip and inconvenience;

Be it therefore further enacted, That in all caſes in which the ſaid foreign duty ſhall have been heretofore paid on ſhips or veſſels of the United States, whether regiſtered at the time of payment or afterwards, reſtitution thereof ſhall be made, and that no ſuch foreign duty ſhall hereafter be demanded on the ſaid ſhips or veſſels.

And be it further enacted, That the act, intituled, "An act impoſing duties on tonnage," ſhall, after the ſaid firſt day of September next, be repealed, and ſhall thenceforth ceaſe to operate, except as to the collection of the duties which ſhall have accrued prior to the ſaid repeal, for which purpoſe the ſaid act ſhall continue in force.

FREDERICK AUGUSTUS MUHLENBERG,
Speaker of the Houſe of Repreſentatives.
JOHN ADAMS, *Vice-Preſident of the United States,*
and Preſident of the Senate.

APPROVED, July the twentieth, 1790.
GEORGE WASHINGTON, *Preſident of the United States.*

(TRUE COPY.)

Th: Jefferson *Secretary of State.*

Early marine legislation.

else collision, grounding or shipwreck will result, and the repair bills will eat up the profits even if the vessel and cargo are saved. The Steamboat Inspection Service is empowered by the Government to examine and license the officers of a vessel and to inspect the machinery and hull. The owner of an American vessel is allowed to load his vessel as he may consider expedient, however, and while he often gets by with a foot or two of extra draft, there are many cases of vessels never being heard from which are doubtless lost on account of overloading. The British shipowner was equally inconsiderate not so many years ago, but the load draft of British vessels is now limited by law, and the Plimsoll mark placed on each side amidships defines the draft, as previously mentioned.

Cargo vessels of a country considered as a group, together with the passenger vessels, form its Merchant Marine and should be invested with the dignity of upholding the honor of the country in the ports of the world. No country can live to itself. Japan of a century ago is the nearest example of a nation of any size attempting to be self-contained. As soon as it opened its ports to commerce, however, it began to grow and develop, until now it is one of the influential nations of the world. The United States has natural resources unsurpassed by any other country, but it is dependent on other countries for certain commodities which are not found or raised here in sufficient quantities to satisfy our wants. We import coffee from Brazil, sugar and iron ore from Cuba, nitrates from Chile, cork from Spain, oil from Mexico, and various other commodities from other countries.

It is generally recognized that this country should be as self-supporting as possible, and for many years our manufactures were encouraged by a protective tariff. But no country can excel in all kinds of manufactures, so that our imports of manufactured goods are of large volume and are likely to continue large. On the other hand, we have for export foodstuffs, cotton, coal, oil and the manufactured products in which we excel. Civilization is advanced by this interchange of commodities and prosperity is dependent on it. Some countries excel in the building or operation of ships. Such countries do most of the carrying trade of the world, and rightly so. But a country as large and powerful and influential as the United States loses a measure of its independence when it allows other nations to carry all of its foreign commerce. It is as much an essential that it shall carry a large proportion of its commerce as that it shall manufacture the major portion of the articles it uses and raise the major portion of its foodstuffs. The more independent we are as regards raw materials and manufactures, the less need there is of a large merchant marine. But if we *must* import and export commodities, we should have a merchant marine of our own sufficient to carry what we really need. If all nations were similarly situated, the proportion of the cargo vessels of the world controlled by each would be distributed according to the amount of the commerce of each nation. Some nations, however, are not able to build or operate vessels economically and cannot afford to do their own carrying. We are not in that class. Under ordinary conditions, we cannot build and operate vessels as cheaply as some other nations. But we can afford to carry our own commerce, just as we could afford to do our own manufacturing. Our independence requires that we shall do our own carrying, and we must not fail to arrange for so doing.

How did we build up our manufactures? We did not buy other nation's manufactures just because they were cheaper than ours, but we put on a tariff that enabled us to compete with foreign goods and to build up our own industries. We must do the equivalent with ships. How? A subsidy would accomplish the purpose with us, as it has with other nations. But a subsidy is liable to abuse, and has not as yet been recognized as proper by the nation at large. Discriminating duties would accomplish the purpose in part, but would help only on vessels importing dutiable articles. Discriminatory tonnage dues would supplement the discriminating duties, and would apply to all vessels entering or leaving our ports. Tonnage dues are the nearest equivalent to the protective tariff, and could be regulated to a nicety to enable this country of ours to have such a merchant marine as our independence requires, without placing any more burden on any section of our people than the tariff did, and could be removed in whole or in part if our cargo vessels, like our manufactures, ever reach the stage of development when no protection is needed, or when all the rest of the world has the same scale of living as ourselves, if such a condition were possible.

The difference in cost of operation is so great, averaging at present probably 50 per cent. more than our competitors, that to balance the difference in freight rates required to offset the extra cost of operation the amount of discrimination in duties, and the difference in tonnage dues, will have to be quite great for awhile at least. The money which reverts to the Treasury on account of the increased tonnage dues on foreign ships will have to be paid out in some form of subsidy, also, as the vessels engaged in long-distance trading and making few entries in a year will need as much assistance as the vessel making many round trips in the same time. The foreign vessel will not have to increase its freight rate appreciably on account of the increased dues, so that the American vessel will not be able to recoup itself for the increased cost of operation on the long voyage by an appreciable increase in the freight rate; and this increased cost must be met by some form of subsidy. The details can be worked out, however, without much trouble, if the American Merchant Marine is recognized as a national problem and treated as a matter affecting the welfare of every citizen, as it should be treated.

We are interested in the modern cargo vessel as an efficient instrument for the carrying of the world's commerce and for the advancement of civilization, and also from a national viewpoint as a means of maintaining and protecting the independence of these United States of America. For this latter purpose, no minor sacrifice should be allowed to overshadow the great gain in independence which will result from our ownership and operation of a large fleet of modern cargo vessels.

The present status of American shipping is anomalous, as the United States Shipping Board has built during and since the war a much larger number of vessels than the country is able to operate advantageously. Ship operation is a very difficult subject, having many ramifications, and must be of comparatively slow growth if it is to be able to endure the vicissitudes to which it is more subject than the average business. The great problem before this country at present is not a lack of vessels, but a lack of experienced operators to manage the vessels. Any marine policy which overlooks this fact is doomed to failure. The difficulty of the task, however, should not deter us from tackling it in earnest, and the nation which bore the honors in shipping a century ago is doubtless able to repeat its performance at the present time.

AMERICA'S PETROLEUM PROBLEM.*

BY

J. O. LEWIS,

Petroleum Engineer, Consulting Engineer, U. S. Bureau of Mines.

THE topic assigned me for this evening's discourse is "America's Petroleum Problem."

This is indeed an important subject and one in which each of us should take personal concern. America's petroleum problem has extended beyond her own borders and cannot be considered as peculiar to herself, but is inseparably involved with the world's petroleum problem. The disposition of the world's oil resources has occupied much attention in recent journalism, both here and abroad. Few of us realize to what an extent petroleum is occupying the thoughts of the world's statesmen. It is a subject which has thrust itself prominently among the problems heritage from the war which now await the world's solution before the dreams of a lasting peace can be made true. It is now one of the chief subjects of international discourse and forms one of our most vexing problems in our relations with Great Britain, France and Mexico.

The sudden prominence into which petroleum has recently been thrust is largely a result of the disclosures of the great war, which caused every people to take stock of its needs and resources. The war provided tests under conditions which showed in unmistakable manner that petroleum had become one of the essentials of modern warfare and industrial life. As the war progressed, the needs for petroleum became more strikingly evident and in large part shaped the policies and strategies of the contending nations. Germany, with only limited oil resources, soon discovered that she must obtain oil to survive, and the drives into Roumania and Galicia were undertaken largely because more oil was needed. England's policies in the Near East, where she was accused of frittering away her resources in unessential military adventures, were largely shaped by the desire to protect her Persian oil fields and to acquire hold on the vast potential oil resources of Mesopotamia. Later an English force unexpectedly appeared in the Baku oil fields on the Caspian Sea when Russia passed under the control of unfriendly hands. Even before truce was declared on the European battlefields, England and France began to put into operation plans which had been laid during the war for acquiring possession of oil resources.

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* Presented at a meeting of the Section of Physics and Chemistry held Thursday, January 27, 1921.

The conviction that oil is a vital necessity, both for commercial development and for military protection, was driven deep into the consciousness of every nation, and every nation, as soon as it could detach itself from the most pressing problems of the war, began to take stock of its needs and resources. The desire to fortify its future by adequate reserves of petroleum is to-day an active element in the policy of each forward-looking nation. It so happens that this country, besides being blessed with abundant oil supplies, has also been most forward in developing her own oil fields and extending the use of petroleum products. At the present we are producing more oil, consuming more oil, importing more oil, and exporting more refined oil than all the other nations combined, and were we to shut our eyes to the future we might say that we are so far ahead of the other nations that concern seems foolish.

Unfortunately the present situation is not a true gage of the future. Our position is more like a spendthrift who seemingly is possessed of unlimited wealth, but who is really squandering both capital and interest. We have been very active in seeking out and developing our oil resources, whereas the rest of the world remains hardly touched. Our energy in quickly finding and obtaining our oil has misled us in regard to our own reserves, so that when we face the future, realizing that to keep up and advance our standards of living we require more oil than any other people, we see that it is important that we be not excluded from the undeveloped oil reserves of the world.

It is not my purpose to discuss the political aspects of the petroleum problem so much as it is to endeavor to set up a background against which you may see America's position and needs. There has been much confusion in the public mind because of the diverse opinions expressed and because of the seeming anomalies involved in the situation. I realize that my opinions do not fully accord with those of some others, so in giving them I shall endeavor to give my reasons also. Your secretary has thought that perhaps the position of Chief of the Petroleum Division, Bureau of Mines, which I recently occupied in the government service, might make such information and opinions as I was free to give you a matter of interest, and I am therefore happy to meet his desires to the best of my ability.

Before I enter into the main part of my subject, I should like to have you consider to what an extent petroleum has entered into our present manner of living. We have reached our modern civilization through progressive conquests of the natural mineral resources. Our progenitors first learned how to use the flinty stones and then to reduce copper, tin, gold, silver and lead from their ores, but it was not until the metallurgy of iron was developed were we able to construct machinery and to make energy serve our purposes. For a source of energy we have used coal and with it the wonders of our day have been done. Coal and iron have provided the foundation upon which science has built the intricate structure of industries of our day.

It has been said that each American is fifteen men—himself and fourteen who serve him. This means that by his resourcefulness the American has multiplied his capacity for producing by fourteen times through the use of machinery. Each of us produces as much as fifteen men could do with their hands and consequently each of us may consume as much as fifteen men doing only manual labor. This fact is the foundation of our superior American standard of living, for we work shorter hours, yet have far more than any other people, for no other people has at command the forces of nature to a like extent. We are a nation of masters, not of servants; we do not battle nature constantly for a meagre existence, but have subjected nature and have compelled her not only to yield us our bare existence, but to yield us comforts and luxuries. Yet we are not satisfied, but are continually striving to add to our retinue of servitors.

Of the servants of man, petroleum is one of the most recently acquired, yet is one of the most essential as well as unique. With the products of petroleum we have been able to conquer where before we dared only to hope. The products of petroleum are pervasive throughout the whole structure of our present existence to an extent not realized by many. To those who are informed the possibility of a loss of this servant gives a feeling of consternation. Automobiles, trucks, tractors, airplanes, motor ships, these and many other machines of peaceful and martial use are commonly known to feed upon petroleum products—but how many stop to think that their automobiles and every other machine, no matter whence its power comes, would be refractory servants indeed without the lubricating oils from petroleum? Friction has always been the thief of power and the engineer must battle incessantly against it. Were it not for petroleum lubricants every moving part would become static. Our whole industrial life would stop.

It is difficult to realize how recent has been the acquisition of petroleum. It has been within the last sixty years. Yet mention of petroleum goes back into remote antiquity. Tars from oil seepages were used in ancient Egypt, and in Babylonia the mud-brick buildings were cemented and protected by natural pitch. The fire-worshippers of Persia, one of the oldest religious sects, worshipped the eternal fires of the gas springs in the southern Caucasus, where the Baku fields were discovered in the last century. Throughout the lands from whence came our culture and religion seepages of oil and emanations of gas abound. In Persia, Mesopotamia, Palestine and in Egypt the geologist of to-day is finding among the ruins of ancient civilizations the oil fields from which the modern civilization will be supplied. Perhaps there is no more striking picture of the material progress of our times than of the modern scientist finding this magic fluid deep under the ground across which countless ages have marched unwittingly.

The modern history of petroleum dates from the Drake well, drilled in 1859 near Titusville, Pennsylvania. From Titusville prospecting was carried northeast as far as Olean, in southwestern New York, and southwest through parts of Ohio and West Virginia into Kentucky. Until 1876 this district, known as the Appalachian oil field, produced all of our oil. From 1876 to 1886 it produced over 95 per cent. of our oil, and up until 1900 it was producing over half of our oil, yet to-day it yields less than a tenth of our production.

After the Appalachian district was discovered oil was found in the Trenton Line fields in western Ohio and eastern Indiana, then in succession in California, Texas, Kansas, Louisiana, Oklahoma, Illinois and most recently in Wyoming.

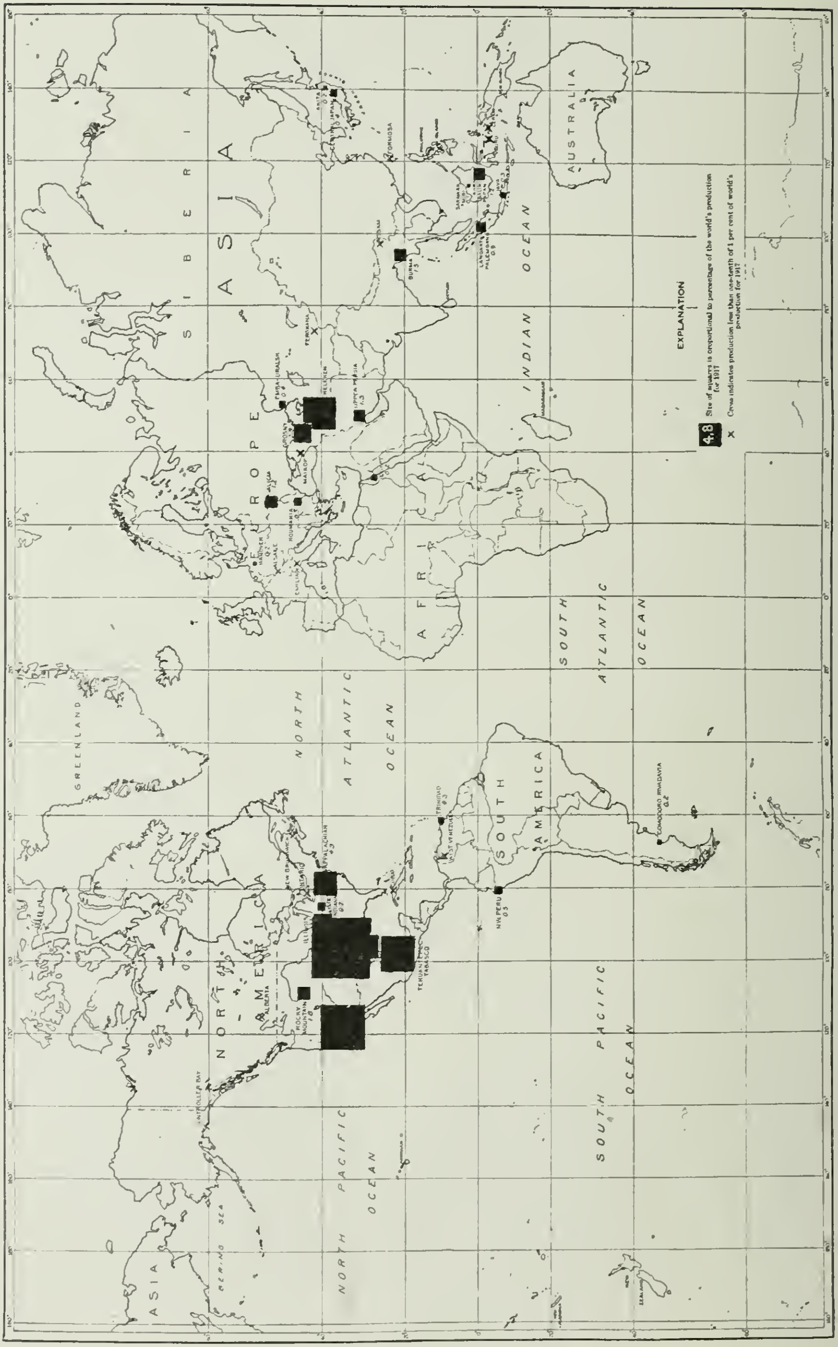
At the present time the States of California, Texas and Oklahoma are the leaders and produce about equal amounts, with

Kansas fourth and Louisiana fifth. The greatest oil district extends throughout the Carboniferous formations of the Mid-continent, including Kansas, Oklahoma, and northern and central Texas. This district yields half of our oil.

After the discovery of oil in the United States it was found in many parts of the world, and there are few countries now which do not either produce oil or in which there is not good evidence that oil does exist. The United States was the first to develop the modern industry, and with the exception of four years, from 1898 to 1902, has kept the lead to the present day. In 1919, the last figures available, the productions of the leading countries were: United States, 377,719,000; Mexico, 87,073,000; Netherlands, East Indies, 15,428,000; India, 8,735,000; Roumania, 6,614,000; Poland (Galicia), 6,054,000; Peru, 2,616,000; Japan, 2,175,000; Trinidad, 1,841,000 Argentina, 1,183,000; Russia, 25,498,000; Persia, 10,018,000; Egypt, 1,487,000; and other countries, 2,112,00; making a total of 548,492,000 barrels for the world, of which 68.7 per cent. was derived from this country. The geographical distribution of the world's production can best be gained from the excellent chart prepared by the United States Geological Survey.

The chart showing the distribution of the world's oil production does not show where the oil's future production is to be obtained nor where the world's oil will be needed. At the moment the United States produces about two-thirds of the world's output and consumes nearly three-fourths. Other peoples have not developed the appetite for petroleum products that we have and it may be expected that, great as will be the growth of demands in this country, the needs of other nations will grow still more rapidly and insistently. The enviable prosperity of our population is caused by supplementing human labor by machine to a degree not yet reached by any other people, and the fact that we consume nearly three-quarters of the world's oil production is indicative of the comparative degree of subjugation of nature's forces to our bidding. But in any thoughts of the future we must bear in mind not only the growth of our own needs but the even greater growth of other nations' needs. We cannot expect to maintain our proportion of two-thirds of the world's output, much less can we expect to consume three-quarters of it. The people of other nations have a just right to insist that they share in the world's resources and that

Fig. 1.



MAP OF THE WORLD SHOWING PRODUCTION OF PETROLEUM FOR 1917
PREPARED BY THE U S GEOLOGICAL SURVEY
1919

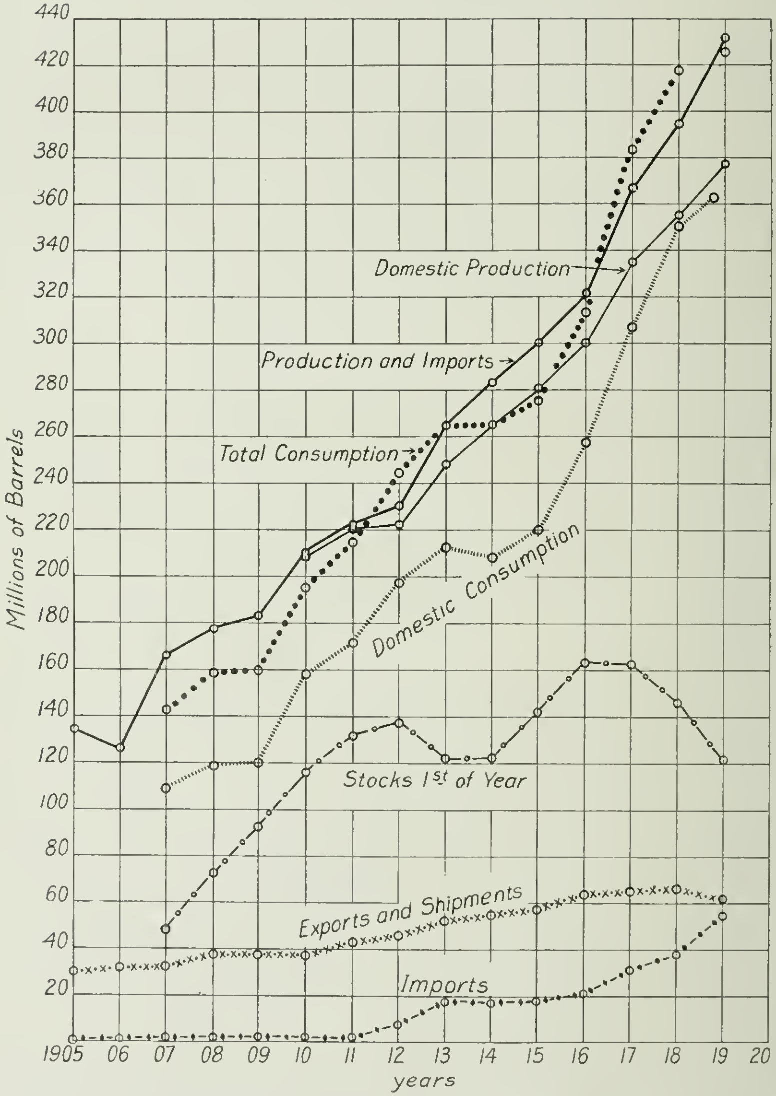
they obtain the fair proportion of their needs. The accusation made against us by some writers across the water that we seek to perpetuate our present overwhelmingly dominant position is manifestly absurd. On the other hand, a policy of absolute exclusion of us from the commercial development of resources under foreign political control—some territories being mandates—is not one which we can countenance with equanimity. There have never been any restrictions to the participation of foreign peoples in our petroleum resources. We should not seek monopoly, neither should other nations seek monopoly nor to build up a Chinese wall around their resources, for these would be, it seems to me, unfortunate policies, which will lead to retaliations and discord among nations.

There has probably been no new resource the demands for which have increased at such a rate as with petroleum. The increase has been relatively greater in recent years, for with the advent of the internal combustion motors applied to automobiles, cars, trucks, tractors, airplanes, etc., the utility of liquid fuels have come strikingly to the fore. Great as has been the growth of these devices, their development is very plainly still at an early stage, both as to the mechanical perfection of the oil-using machines and as to the adoption of these devices into our economic structures.

As sources of power and heat the liquid fuels have peculiar advantages, of which there is growing appreciation. It is particularly adapted for small power units, more especially for automotive purposes, either on the water, under the water, on land, or in the air. The field for the pleasure car has been well developed in this country, but the utility of the truck has untold possibilities in short-hauled transportation, not only in our industrial but in our farming and mining centres. It promises to work wonders in solving transportation problems, not so much in supplanting the railroads on long hauls, but as their accessories in gathering and distributing on short hauls, which is the most efficient use for the truck and the least efficient for the steam road.

As small power and motive units on the farm, petroleum-using motors promise to go far to solve the farmer's labor problems. To-day our farmers are the greatest producers in the world per man, though not per acre, yet the farmer has not had his share of our fourteen mechanical servants. With the auxiliaries made

FIG. 2.



Production, imports, stocks, exports and consumption of petroleum in the United States as shown by the Bureau of Mines.

possible by petroleum products, it would seem as though the farmer might have at his disposal the labor-saving devices of which he is most in need.

One cannot contemplate the future of the airplane without being carried away with visions. It may not supplant the means of transportation of to-day in as many ways as some of its early advocates believed, but it has proved universally true that new inventions tend, perhaps, even more to extend into new fields of usefulness not previously at man's disposal than to supplant previously used devices. For the airplane, its peculiar features of speed beyond all former conceptions and its capacity for straight-line travelling, independent of water, plains, mountains, roads, or railroad tracks, place it in a class by itself and give us a device of a kind not previously known, the use of which will call for new conceptions of transportation.

On the sea, fuel oil has unique advantages. Our Shipping Board has claimed repeatedly that only by fuel-driven ships would we be able to overcome the other advantages enjoyed by other maritime nations.

The subject of our future needs cannot be discussed without consideration of the military features. The great war demonstrated in unquestionable manner that petroleum is essential in modern warfare—one of the things without which a nation is hopelessly inferior. The modern army moves in trucks and automobiles and on small railroads using gasoline engines. The big guns are mounted on tractors. Tanks are one of the most effective machines of modern warfare and the airplane is absolutely essential. On the sea, the submarine is possible only with liquid fuel and the fighting ships are inferior without oil fuel. Even the great dirigibles for both land and sea will use in the next war helium gas supplied from our oil fields. Recently the papers reported that in sham battle the British fleet was demolished in half an hour by the air fleet.

Thus for as long as it is necessary to guard our interests at home and abroad, adequate petroleum supplies are essential for our protection.

I have dwelt somewhat at length on these matters relating to the utility of petroleum and our future needs because I believe that petroleum is one of our most useful agents and one in which every individual in this country has a personal interest. I believe that it is capable of extending our capacities far beyond their present scope and will place at our disposal many more than the fourteen mechanical servitors which we now are said to have. Our needs, therefore, are not only to retain these fourteen servants, but to employ in the future the others which adequate petroleum supplies will give us.

I have pointed out along what lines our needs are trending. How much they will be I cannot say. It would seem as though there were no limits to our capacity for absorbing petroleum supplies and that demand is therefore the same as supply—in other words, our needs are what we can obtain. The question then becomes—looking not at the immediate future, but over a long term of years—how much can we obtain and how can we best use what we get?

In considering our oil resources and whether or not they are adequate, we should keep in mind the fact that it will not suffice merely to maintain our present production, but that it is desirable that production be greatly increased in order that we may fully realize upon the benefits to be derived from ample supplies. Yet at the same time we should be provident and far-sighted. The future should not be sacrificed too much for the present, nor should present supplies be conserved for a far distant future whose needs we cannot know, for in these days of wonders a generation or two hence may have powers which will make petroleum of little concern to them. Petroleum supplies should be sought and developed to the extent that this generation can use them wisely and conservation of our resources should be applied, in my opinion, with sane providence and not hoarded for an indeterminant future for the use of a generation which perhaps will not need them.

Until recent years our country produced more oil than we used and we exported more than we imported. We had developed our fields faster than we had developed uses for petroleum. But now we import more than we export, and no longer are we a self-sufficing nation. It is true that production has increased in recent years—increased tremendously—but our consumers have found ways of using oil faster than our producers have found new supplies, and were it not for the opportune discovery of the extraordinary Mexican fields this country would have experienced great stringency during the past several years. Whether or not the supplies underground are as great as our optimists hope, or as little as our engineers estimate, no one disputes the fact that our production must be supplemented to a larger and yet larger degree in future years from foreign supplies. America's petroleum problem has therefore taken on an international aspect.

In considering our domestic resources I desire first of all to take stock of the underground reserves in our oil fields and to leave the questions of substitutes till later in my discourse.

In respect to our underground supplies there are two schools of thought. The opinion of the practical oil man, or the man who is strongly interested financially in oil, is usually very hopeful. The practical oil man usually believes that there is no way of estimating oil supplies underground; that in the past new fields have been found as needed, and so in the future there will always be new sources of supplies discovered concurrently with our growing needs. His is an abiding optimism, frankly disclaiming proof and denying that proof either one way or the other is possible.

The other school is that of the engineers, particularly technical men in the employ of the government. They have endeavored to reduce the estimation of oil reserves to an engineering basis, and while disclaiming great accuracy yet confidently believe that their figures are a useful gage of our resources and do show about what we may expect in future.

It is not possible to go into a detailed discussion of the basis of such estimates, and I will content myself by saying that, taken as a whole, these engineering estimates are reasonable probabilities, are sincerely made, and represent the best that can be had, and it would be folly to ignore them for nothing more substantial than vague optimism. It might perhaps be pertinent to point out here that the large increases in production obtained in recent years, which have sustained the oil man's optimism, are primarily due to the great success in finding new fields by those geologists whose estimates of future production the practical oil man treats with so much skepticism. It is entirely possible, though in my opinion unlikely, that, upon the basis on which made, the estimates of the geologists may be much too low, but again they may be too high. In any event it gives us something sufficiently dependable upon which to base our policies for the future.

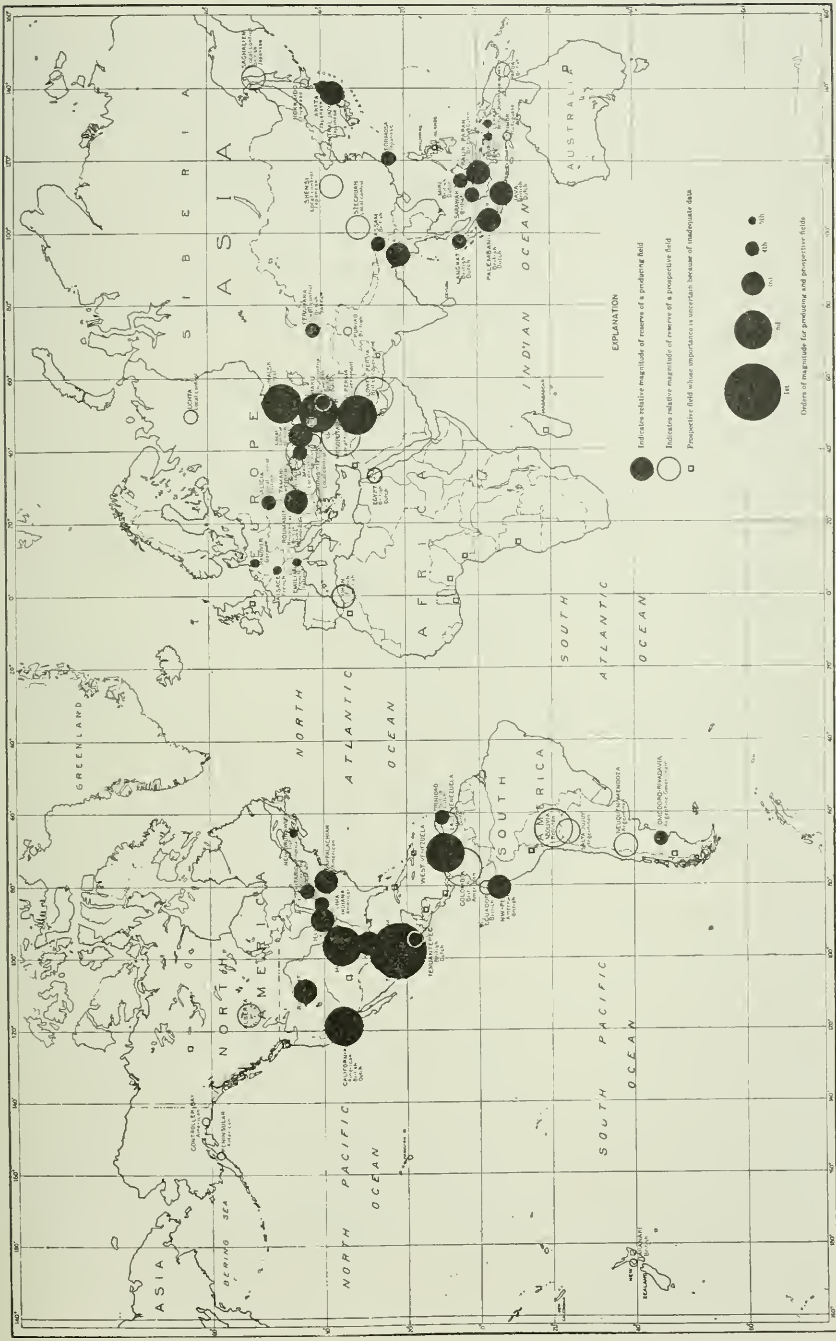
The opinions of the first school are of course not reducible to figures. The United States Geological Survey has estimated our petroleum supplies as over 40 per cent. exhausted, and that were it possible—which it is not—for these reserves to be drawn upon continuously at the present rate, they would last not two decades.

Here is a picture which, set off by itself, is indeed a gloomy one, but I hasten to add that though we should not pass this by without learning the lesson it teaches, we are not in such desperate plight as one might believe at first sight. The estimates of the Geological Survey are based on the methods of oil recovery common until the present time, but there is excellent reason to believe that by methods recently applied, the recovery of the oil, held by capillary forces in the multitudinous pores of the oil sands, will be greatly increased. For myself, I believe recovery in the past has been less than 20 per cent. of the oil sand contents, and I am of the opinion that recovery may be increased by at least half, and perhaps by as much again as is now being obtained. This latent resource and the oils which may be derived from coals and bituminous shales, together with the known and probable oil reserves of other countries which have not been so intensively developed, make a picture not so dismal.

It has been found in recent years that oil is widely distributed and is likely to be found wherever there are large areas of unaltered sedimentary strata. In any region where oil occurs there is most always visible evidence in the nature of seepages, tars and gas springs—sometimes these surface showings are very plain, as in California, Mexico, Trinidad, Russia, and elsewhere, but sometimes they are not so evident and are not reported until close investigations are made by those experienced in oil finding. Since oil has become of such universal interest, reports previously neglected are being investigated, and there is now going over the surface of the globe an intense search for evidences of oil regions. Many such regions have been discovered and many are now being tested. Although information on the extent and value of these deposits is still meagre, there is enough to indicate that vast fields exist in known parts of the world and that the possibilities of the as yet undiscovered fields are perhaps still greater.

The world's petroleum resources was the subject of a recent paper by Dr. David White, chief geologist of the United States Geological Survey, who probably more than any other man is qualified to write on this subject. Doctor White has made estimates which, though admittedly of the most preliminary nature,

FIG. 3.



WORLD MAP OF DEVELOPED AND POTENTIAL PETROLEUM RESERVES
PREPARED BY THE U S GEOLOGICAL SURVEY
1919

are the best extant and do give a useful picture of the world's oil possibilities and where they are located. He has estimated that about half of the world's potential production is to be found in the Americas and half in the eastern hemisphere. Of the world's reserves something like one-eighth (not counting the additional recovery previously discussed or oil from shales and coal) is in the political possession of the United States, so it may be seen that our present position of producing two-thirds the world's oil means but little in the light of the future, particularly when one considers what our proportionate needs are going to be and how much more rapidly our own resources are being depleted than in other countries.

The chart of the oil resources of the world—not present production—is perhaps the best picture of the comparative magnitude of the various countries' reserves and of their distribution. It will be seen that Mexico, Venezuela, Colombia, Peru, Bolivia and Argentina are estimated to have large reserves. Mexico, as is well known, is wonderfully supplied, and enormous quantities are now being imported from her fields. Venezuela and Colombia have demonstrated fields, but their exploitation is retarded by difficulties beyond the conception of those of us not familiar with the tropics. But in a few years they will be supplying oil in large quantities. Peru has been producing oil for many years and certain fields in Argentina have likewise. Bolivia is still undeveloped and will be accessible only with great difficulty.

Canada has produced oil in the Ontario district almost as long as this country. For many years seepages have been known to extend over a vast area in the northwest provinces, and recently there have come reports of important discoveries in the Far North that make the possibilities even better than accorded Canada on this chart.

In Europe oil is produced in Roumania, Galicia, Italy, Alsace, and near Hanover in Germany, but oil is believed to exist in other parts of Europe. The Near East is destined to be the great oil centre of the eastern hemisphere. The Caspian district and Persia have prolific fields and signs are abundant throughout Mesopotamia, Syria and Palestine. The Transcaspian district also contains abundant indications of oil and there are tremendous areas of Siberia and China covered by unaltered sedimentaries which might contain oil. Oil is produced in India and on many islands of the East Indies; oil is also found in Japan, Formosa, and Saghalien. Indications of oil are abundant in the Philippines, oil has been found in small quantities in New Zealand, but as yet not in Australia.

In Africa oil is found in Egypt and will doubtless be found in Algeria. Oil is also known to exist in Portuguese Angola, but the vast area of Africa remains as yet practically unexplored by the oil geologist, and undoubtedly many fields now unsuspected will be found in future.

It is evident that this world is not in danger of running out of oil supplies overnight, and that if the political and commercial situations affecting the oil supplies of the world are worked out with reasonable equity, we should have oil for as long as the future needs can be reasonably foreseen. We may not have all that we desire—perhaps not all that we could use, but probably all that is needed to supply those demands for which satisfactory substitutes cannot be found.

The realization of the desired end will not be without difficulties; there will certainly be keen commercial and political rivalries, as indeed there is to-day, but if we apply ourselves to the problems involved they will almost certainly be solved. But if we do not apply ourselves opportunely, then I am of the opinion that we shall find ourselves at keen disadvantage in future as compared to more enterprising nations, and that this generation will in later years be blamed for its improvidence. The efforts should be made not only in keeping foreign supplies open to our nationals, but in developing every possible domestic resource which promises to supplement the oil supply.

More than any other natural resource, petroleum has gripped the consciousness of the peoples of the progressive nations. It has everywhere proved a more vexing problem in the disposal of ownership rights to the individual by the nation than with any other mineral. It is unique in its nature and in its mode of occurrence, and has therefore been treated as a thing apart. More attention has been given to nationalizing it and it has been considered the peculiar property of the state more than any other natural resource. This trend of thought—to consider the petroleum resources the property of the nation—has been greatly accentuated by the lessons of the war; thus we find England, whose dominant thoughts have always been the individualism of the citizen and free trade, going far in nationalizing oil resources, in excluding other nationals from her colonies, and of actually participating in a controlling way in an oil company competing on a grand scale in the oil industry throughout the world.

When one considers England's peculiar military and commercial position, one can readily appreciate England's concern in obtaining adequate oil supplies. Her present production is but a few per cent. of the world's output and is not to be compared with ours. That England is forced to take steps necessary for self-protection must of course be conceded, but whether the steps which have been taken are wise and whether they constitute infringements on the rights or interests of others, is quite another matter.

The efforts of our government to remove discriminatory policies and to combat the tendencies towards exclusiveness in petroleum resources has centred around the acts of the British and Mexican governments largely because they were in position to affect our interests most seriously. It is perhaps unfair to couple the two governments in the same sentence, but they both are parts of the same general situation. There are certain interests which look upon the Mexican situation as *the oil problem* and others who think of the British situation as *the oil problem,* but as a matter of fact both should be considered as only features of *the oil problem,* for the same tendencies in various forms are displayed in policies in effect or under consideration by France, Russia, Japan and the countries of Latin America.

It is hardly necessary to detail how these tendencies have been manifested in the acts of the interested government. They have taken the form of complete nationalization of petroleum resources by some governments, of restricting development of resources to the nationals of the country, of various degrees of restrictions and discriminations on aliens and of active governmental participation in the oil industry, of which the Anglo-Persian Oil Company, in which the British has controlling interest, is the best example.

The Petroleum Policy of the British Government has been actuated primarily by her special situation. Some years ago England discovered that oil made a far superior fuel than coal for naval and merchant marine uses, and to such a degree that the Admiralty determined to construct an oil-burning navy, despite the fact that coal could be obtained at home, whereas oil must be brought overseas and could not be obtained in sufficient quantities from even her own colonies and possessions. This situation influenced the Admiralty to take the unprecedented step of embarking in the oil business. The Anglo-Persian Oil Company was formed in partnership with a large British oil company to prospect and exploit a concession of half a million square miles in Persia where, after several unsuccessful ventures, prolific oil pools were opened up shortly before the Great War.

Since the war the Anglo-Persian has been greatly strengthened financially, and its activities have been extended throughout the British Empire. In Australia partnership corporations have been formed with the Commonwealth, which are practically monopolistic. Elsewhere there is evidence of activities which seem to make certain commercial competition between our larger oil companies doing business abroad with the Anglo-Persian. It need hardly be pointed out that such commercial rivalries, when one party is a government, are likely to make many delicate situations which will be fruitful of discord between the two peoples. Our government apparently views this situation with apprehension, for while England is doubtless within her rights, yet the exercise of these rights in this manner would seem to be an unfortunate precedence that is likely to make obstacles in working out that international comity which both peoples desire.

Many of the acts of various governments about which this country is concerned are also within the internationally recognized rights of the nations, yet the exercise of these rights seems to be unfortunate. We have the same rights, but we have never exercised them, nor do we now, yet we may be compelled to do so for self-protection. In England the petroleum policy of the government—particularly its partnership with the Anglo-Persian—has been criticized in Parliament largely because it may lead to international troubles, but the venture in Persia, by reason of the exceptional value of the discoveries there made, has fortified the proponents, and it would seem that the policy is to be pursued with increased vigor.

Although many of the acts and policies to which this government shows concern are clearly within the recognized rights of the nation, others are contrary to international usage, or to diplomatic understandings. The Mexican situation hinges around what is said to be in effect an attempt at the confiscation of vested rights acquired legally by our citizens under the laws of the country as they then were. The partitioning of the oil rights of Mesopotamia between England and France and of Asia Minor between England, France and Italy through the so-called San Remo and tripartite agreements, respectively, are both against our traditional policy of the " open door " and against the plain understanding given to our representatives as to the nature of mandates when this form of political control was under discussion at Versailles.

These exclusive nationalistic tendencies our government has been combating these last two years particularly, and although our State Department has been under criticism, I think it can be fairly said that much headway has been made—more, in fact, than is apparent, for the greater accomplishments have probably been in preventing the perpetuation of war measures and the accomplishments of purposes under consideration than in recessions from positions already announced. Fortunately representations were started soon enough that many acts contemplated by foreign governments had not yet been put into effect. Yet much more needs to be done and the oil situation is yet to be settled. It is to be hoped that we shall not be compelled to retaliate and exclude other nationals, to embargo petroleum exports, or for the government, directly or indirectly, to get into the oil business.

Before leaving this subject I would like to call your attention to a need of our national government which the oil situation has disclosed. Our government is perhaps better equipped with technical bureaus than any other government, but there has been in the past a lamentable lack of coördination between the various agencies of the government. Fortunately steps were taken during the war for making available useful information from one department to another. The oil situation illustrates the value of this move, for it was called to the attention of our Department of State by the technical bureaus and they supplied much of the necessary information upon which action has been based. There is, however, real need for a system for coördinating the activities of our many government agencies in such way that the utility of government as a whole may be increased. There has been much talk of duplication of efforts and functions in the departments. From my own experience I judge this to be more seeming than real. A greater need is the further development of agencies for seeing that the many activities of the government function as parts of one large machine rather than of a multitude of small independent machines.

I have endeavored in this discourse to bring out how desirable for our continued prosperity are abundant petroleum supplies. The rate of our future growth will, to a very considerable extent, be determined by whether or not adequate petroleum supplies will be available when needed. If they are available, we shall have many more added to our fourteen mechanical servants, and we shall have more conveniences, more pleasures and an added degree of universal prosperity. The desired supplies of petroleum in future cannot be obtained from our own oil wells, which were adequate to the past, and we must therefore turn to other sources of supply, both home and abroad. This constitutes America's Petroleum Problem—how are we to obtain the necessary petroleum products that our growth be not stunted?

Like most big problems there is no single solution—the problem will, in my opinion, be solved by the combined effects resulting from several lines of attack. These can, however, be grouped into two broad phases—one, the maximum development of home resources; two, the securing of foreign supplies.

The foreign situation has, I believe, been fairly well covered. There is, in my opinion, oil supplies adequate to ours and the world's needs for an indeterminate time. The problem is to secure to ourselves our needed portion. Our efforts, therefore, should be exerted towards influencing foreign governments to do away with their exclusive policies and to let oil be developed under the normal course of trade, in which case I think it can be safely said that our oil companies will take care of the situation when foreign governments reciprocate our policy of the open door.

I would like to advance one more thought in regard to the foreign situation. At the present time we have many things to sell which Europe needs but cannot buy because the European countries cannot pay in gold or goods and their credits have been stretched to the breaking point. When a country sells more than it buys the time is reached when the difference must be invested by the creditor nation in permanent securities or resources of the debtor nation. This was the trade relationship between England and the debtor nations, and accounts for the tremendous sums invested by her peoples abroad. But we are new as a creditor nation and our people, generally speaking, are not experienced in foreign investments and will not readily absorb them. Mining—more particularly—is, however, an exception. It would seem as though the undeveloped oil resources of England and France might be used as a basis of credits that would absorb millions—perhaps billions—of dollars in permanent investments which in turn would open up resources that would be sold back to us in future and thus help to equalize trade balances, yet curiously enough the one kind of foreign investment which would most attract our investors and would seemingly measurably improve exchange rates and trade relations, is shut off from us.

But even should the foreign situation be settled to our entire satisfaction, we should by no means neglect our domestic resources. We should do everything possible to stimulate the wise development of other sources of oil supply, from oil shales, coals, and of oil substitutes from organic materials. This should be coupled with developing methods of getting more values out of such oil as we now have through better methods of production, refining, of utilization, and by substituting coal and other fuels from the larger reserves where possible. The home situation is thus primarily a technical problem, whereas the foreign is primarily a diplomatic problem.

It is not my desire to go into details regarding the other resources which might be developed for oil. They may, however, be briefly outlined. From our oil fields I personally believe there may be obtained by new methods at least 50 per cent., and perhaps 100 per cent., more oil which formerly was left unrecovered in the sands. From oil shales far more oil can be obtained than from our oil wells. A very great quantity of oil products can be obtained from coals. From waste organic materials alcohol may be obtained to substitute for gasoline.

Together these latent resources constitute an enormous reserve awaiting the technical knowledge and the right economic conditions for development. It must be kept in mind, however, that, speaking generally, these resources are to a very great extent dependent upon higher prices for petroleum products. To a limited extent (with the possible exception of oil shale) all are being commercially exploited to-day, but the large-scale development necessary to supply any large proportions of our needs will come gradually as our technical knowledge is developed and as our unsupplied needs force prices upward.

Tremendous improvements can be made in the utilization of petroleum which will enable us to get far more use from the oil than is being done to-day. The principal uses of petroleum are for lubricants, fuel for internal combustion motors, illuminating oil, and oil for heating or steam raising. The greatest opportunity for economy in use is in the further development of motors for heavy oils. Half of the petroleum products are heavy fuels used for heat and steam raising. All, or nearly all, should be used for generating power in internal combustion motors, for by so doing experience has shown that three times as much power can be obtained than when the oil is burned under boilers.

Fuel oil is particularly adapted to marine use, and our shipping board has constructed something like three-fourths of its merchant marine as oil burners, but unfortunately as steamers. To my mind it is a fit subject of public inquiry why more motor ships were not constructed and what plans, if any, exist for changing these steamers into motor ships in future. The motor ship is a demonstrated commercial success and England is replacing the steamships sunk by the Germans largely by motor ships. The shipping board is the largest consumer of fuel oil in the world, and its steamships not only use more oil, but divert oil from other consumers and induce peroids of shortage and high prices which otherwise would not be so acute.

There has been so much talk recently of embargoing exports, of retaliatory measures and of holding the oil in the ground for our own future needs that these subjects should receive some mention. It seems to me that the petroleum situation calls more for constructive thinking than for obstructive thinking, and these various policies of inhibition, in my mind, should be considered only as unavoidable choices in lieu of more satisfactory solutions. We might unfortunately be compelled to take retaliatory steps if forced to do so by lack of reciprocity on the part of foreign governments, but, in my opinion, it should be done only in a sense of compulsion.

As for embargoing exports, that seems to me to be mainly based on very superficial reasoning. If we were not already importing more than we export, this might have a solider basis of justification. As things are now, we import from Mexico not only enough for our own needs, but also for re-export. We therefore get the profits from refining and selling this oil. If we embargoed exports, the European nations which we now supply would purchase their crude from Mexico and refine it there or in Europe, and the net result would be that in the end we would have no more oil than before and would lose these extra profits besides incurring the ill will that would be engendered by such a course.

The embargoing of exports and retaliatory measures in general should, in my opinion, be considered only as means to an end—that is, for inducing reciprocity in petroleum. Such measures should not be applied except as a final means to gain this end, for, in my opinion, they are founded on unsound principles, and ultimately are likely to prove to our own and everyone's great detriment; for if we are going to need oil from other countries in future it would seem folly to set a precedent of refusing oil now that we have it to those who need it now, but who hold the keys to the future in their hands. Yet as a temporary expedient we could employ our present position to great advantage, for if we should cut off our supplies to foreign countries now, it would be exceedingly embarrassing to them, for it would take a number of years of concentrated effort before they could replace these supplies from their own resources. This applies particularly to certain qualities of lubricating oils which so far have never been obtained from other than certain American crudes. Such a course would therefore be a potent weapon, but one which surely we would not wish to employ unless our hand was forced.

In conclusion I may state, as my opinion, that I do not apprehend any long-continued oil famines. I believe that this generation, and probably many more generations, will have sufficient supplies of petroleum products. But it must be kept in mind that this statement applies to the broad view of the situation, and that temporary periods of undersupply are likely to alternate with periods of oversupply, for the oil industry is particularly liable to such fluctuations, because each year new fields, not heretofore known, must be brought in to make up for the declining productions of the older fields. Because of the uncertainty of discovering and developing such new fields when needed, there is always the possibility that the next year not enough new production may be found to meet that year's needs.

In so far as our government is concerned, it should do everything possible to stimulate the development of home resources and of the discovery of more effective ways of using our oil supplies.

This can be done by supporting technical investigations and by other proper means of encouraging the greater extraction of oil from our fields, the development of oil shales, of methods of retorting oil from coals, for obtaining substitutes from 'organic waste materials and for the discovery and application of more efficient methods of utilization. So far as the foreign situation is concerned, our government, if properly supported by public sentiment, should at least be able to modify the objectionable foreign policies which hinder our nationals from going abroad.

If we apply ourselves in time, I see no reason why America's Petroleum Problem cannot be solved, but I must also qualify my optimistic opinion by stating that this desired end will not be attained without effort on our part. America's Petroleum Problem, in my opinion, will not solve itself, but America must apply itself diligently to solve its Petroleum Problem.

Dilatation and Compressibility of Liquid Carbonic Acid. C. F. JENKIN. (*Proc. Royal Soc.,* A690.)—Compressibilities are tabulated for temperatures ranging from –37° C. to 30° C. At the latter temperature and under a pressure of 1100 lbs. per square inch the coefficient is .00114. At the same pressure the coefficient is only one-sixth as great when the pressure is raised to 1400 lbs. per square inch. The remarkable properties of liquid carbon dioxide will be seen more clearly when it is stated as follows: At 30° C. and 1100 lbs. per square inch an additional pressure of one pound per square inch reduces the volume of the liquid by more than 1 per cent. An approach to the critical temperature with the pressure maintained constant is always accompanied by an increase of the coefficient, while an increase of the pressure, the temperature being maintained constant, results in a lowering of the coefficient.

The table of dilatation likewise contains remarkable results. At 30° C. at 1100 lbs. pressure per square inch an increase of a single degree C. causes the volume to increase by .0517. For gases, not liquids, under normal conditions the corresponding quantity is .00366, or only one-fourteenth as much. So small a coefficient as that of gases was not found for liquid carbonic acid until the relatively low temperature of –30° C. was reached and then only at a pressure of 500 lbs. per square inch. The dilatations increase rapidly as the temperature rises and approaches the critical temperature; for example, it is about eighteen times as great at 30° C. as at –37° C., the pressure being 1100 lbs. per square inch in both cases, and also it changes greatly with changes of pressure.

The data furnished are the results of careful experiments by the Professor of Engineering Science at Oxford.

G. F. S.

Is the Atom the Ultimate Magnetic Particle? A. H. COMPTON and O. ROGNLEY. (*Phys. Rev.*, November, 1920.)—In 1915 K. T. Compton and E. A. Trousdale investigated the diffraction patterns produced by X-rays passing through a magnetic crystal when it was not magnetized and again when it was magnetized. They obtained a negative result. If the ultimate magnetic particle consists of a molecule or other group of atoms the magnetizing of the crystal with the accompanying rotation of the magnetic particles should bring about a different arrangement of the atoms within it, and this in turn should be followed by a change in the diffraction pattern. The failure to discover this change furnished a strong argument against the molecule being the magnetic particle. Is it, then, the atom or something even smaller?

The atom now, according to Rutherford, consists of a central nucleus with a resultant positive charge about which electrons are revolving. When a magnetizing field is applied to a crystal, the atoms, if they really are the magnetic particles, will turn about until their axes are oriented on the whole in a direction different from that previously maintained. Fortunately, this should produce a result capable of detection. The intensity of a beam of X-rays reflected from the face of a crystal is dependent upon the arrangement of the electrons with respect to the face. Any turning of the atom should therefore manifest itself by a change in the intensity of the reflected beam. It was such a change that the experimenters sought, but failed to find.

X-rays from the same target were divided; some passed to the right and were reflected from a crystal of rock-salt into an ionization chamber; others went to the left and were reflected by a crystal of magnetite into another similar chamber. These two chambers were joined to a quadrant electrometer so as to produce deflections in opposite directions. Adjustments were made until no deflection was obtained. Then the magnetization of the crystal was changed by an electromagnet. Changes in intensity as small as 1 per cent. could have been detected, but no such changes were observed. The applied magnetization was, however, sufficient to magnetize the crystal only to one-third of saturation. It seems that we can not regard the atom as the magnetic particle in consequence of the negative outcome of this experiment. We are thus seemingly reduced to the positive nucleus and to the electrons. Barnett's production of magnetization by mechanical rotation and Stewart's obtaining of rotation by magnetization are interpreted to show that the motion of negative electricity produces the chief part of ferromagnetism, and this rules the positive nucleus out. The authors, after a careful examination of the evidence at hand, draw the modest conclusion, " The magnetic properties of matter are due either to the nucleus of the atom or to the individual electrons. Auxiliary evidence, however, indicates that the electron is the more probable elementary magnet."

G. F. S.

HARMONIC OSCILLATIONS.*

BY

A. F. ZAHM, Ph.D.
Bureau of Construction and Repair, U. S. N.

PART I. PREAMBLE ON STRUCTURE OF THE EQUATIONS.

INTRODUCTION.

Purpose of Treatment.—In the study of airplane stability one frequently employs the equations of harmonic motion, both linear and angular, and especially of damped harmonic motion. It is therefore useful to have the equations and properties of such motion presented in a form convenient for ready reference and application. Some of the more usual of such equations and properties are given in the present elementary treatment, prepared for the Bureau of Construction and Repair in its Aerodynamical Laboratory at the Washington Navy Yard. The text drawings were made by Mr. G. C. Hill.

Definition.—Harmonic motion in general may be defined as a movement whose acceleration is toward an equilibrium position and is proportional to the displacement of the moving object from that position. Such motion may be either frictionless or retarded by friction, say of the surrounding medium. A simple pendulum bob, for example, when making small excursions about its position of rest, executes harmonic motion, whether performing plane or compound vibrations, whether moving undamped in vacuo or damped in a fluid such as air or water; for, as is well known, its acceleration is always toward the point of rest and proportional to the distance therefrom. Similarly a torsion pendulum gently twisting about its axis performs harmonic motion.

A harmonic oscillation is called " free " when subject only to acceleration within the vibrating system; " forced " when accelerated from without. A free oscillation is called " damped " when impeded by friction or other deadening resistance; " undamped " when void of such resistance.

In this text the damping retardation is assumed proportional to the speed; the external acceleration is taken as either a constant or a sine function of the time.

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* Communicated by the Author.

DEVELOPMENT OF THE HARMONIC EQUATIONS.

Equation of Damped Straightaway Motion.—If a moving particle is opposed only by a force proportional and opposite to its velocity, say the resistance of a fluid, it will pursue a straight path till brought to rest. And if *ds* be the travel in time *dt,* the damping force and acceleration may be written

$$R = -2ma\dot{s} \qquad (1)$$

$$\ddot{s} = -2a\dot{s} \qquad (1')$$

in which m is the mass of the particle, and $2a$ is for convenience taken as the "*damping coefficient.*" The quantity $2a$ is positive and may have any fixed value, depending on the opposing agency and the mass of the accelerated particle. It is in fact found from the force equation of the particle by dividing the coefficient of $\dot{s}$ therein by the mass.

Equation of Simple Harmonic Motion.—Similarly if the only opposing force, say an attraction or an elastic resistance, is proportional and opposite to the displacement from rest of the particle, its force and acceleration can be written

$$F = -mb^2s, \qquad (2)$$

$$\ddot{s} = -b^2s, \qquad (2')$$

in which b^2 is the "*displacement coefficient*" or "*stiffness.*" The quantity b^2 is positive and may have any fixed value, dependent on the restoring force and the mass of the accelerated particle. The movement represented by (2′) is known as a "simple harmonic motion." It is, as will be shown by equations (9), (10), the rectilinear oscillation of a point whose acceleration is proportional and opposite to its displacement from rest.

Equation of Damped Harmonic Motion.—If the two foregoing forces act conjointly, the equation of motion becomes

$$\ddot{s} + 2a\dot{s} + b^2s = 0, \qquad (3)$$

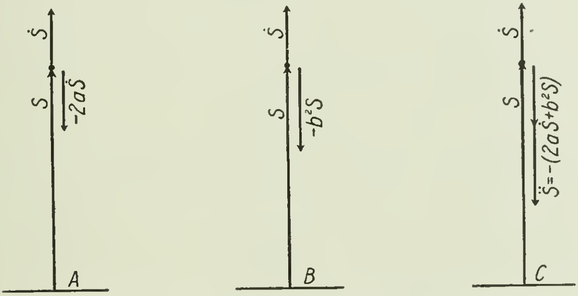
in which each term is an acceleration, and $\ddot{s}$, the resultant of the other two, is the actual acceleration of the particle at any instant. The complete treatment of this equation, therefore, comprises both undamped and damped free harmonic oscillations of a point in a straight line.

Graphical Composition of s, $\dot{s}$ and s.—Fig. 1 illustrates the relation of the various vector quantities in the foregoing equations. In sketch *A* the particle is seen moving in the positive direction of s and opposed by a force proportional and opposite to s, which causes the acceleration $-2\,a\,\dot{s}$; in sketch B the particle moves from its position of rest opposed by a restoring force proportional and opposite to s, which causes the acceleration $-b^2 s$; in sketch C the particle moves from the point of rest opposed by both said forces, which beget the acceleration $-(2\,a\,\dot{s}+b^2\,s)$. The coefficients are written $2a$ *and* b^2, rather than a and b, merely for simplicity in subsequent operations.

METHOD OF SOLVING THE EQUATIONS.

In order to divest of mathematical detail the analysis of the differential equations of motion, a preamble is here given on the usual method of integrating such equations.

FIG. 1.



Component and resultant accelerations of a particle performing rectilinear free harmonic oscillations.

Solution of the General Differential Equation.—The equations of free harmonic motion belong to the class known as linear differential equations with constant coefficients and second member zero, and have the general form

$$\frac{d^n y}{dx^n} + p_1 \frac{d^{n-1} y}{dx^{n-1}} + \cdots\cdots + P_n y = 0, \quad \cdots\cdots\cdots\cdots (4)$$

where $P_1, P_2, \ldots P_n$, are constants.

To solve this by Euler's method, substitute e^{mx} for y. The first member of the equation then becomes $(m^n + P_1\,m^{n-1} + \ldots + P_n)e^{mx}$, which equals zero if

$$m^n + P_1 m^{n-1} + \cdots\cdots + P_n = 0, \quad \cdots\cdots\cdots\cdots\cdots\cdots (5)$$

This latter is called the auxiliary equation to (4). Since each of its roots $m_1, m_2 \ldots m_n$, satisfies (5), $y=e^{m_1x}$, $y=e^{m_2x}$, etc., must satisfy (4). Hence the complete solution is

$$y = C_1e^{m_1x} + C_2e^{m_2x} + \cdots\cdots + C_ne^{m_nx} \ldots\ldots\ldots\ldots (6)$$

For example, to integrate

$$\frac{d^2y}{dx^2} - 9y = 0,$$

the roots of its auxiliary equation,

$$m^2 - 9 = 0,$$

are 3 and −3. Hence the complete solution is

$$y = C_1e^{3x} + C_2e^{-3x}$$

Case I. Imaginary Roots.—In case the auxiliary equation (5) has imaginary roots, any pair of such roots, say $m_1 = \alpha + i\beta$, $m_2 = \alpha - i\beta$, where $i = \sqrt{-1}$, has the corresponding solution

$$y = C_1e^{(\alpha+i\beta)x} + C_2e^{(\alpha-i\beta)x} = e^{\alpha x}(C_1e^{i\beta x} + C_2e^{-i\beta x})$$

$$= e^{\alpha x}[C_1(\cos\beta x + i\beta\sin x) + C_2(\cos\beta x - i\beta\sin x)]$$

$$= e^{\alpha x}(A\cos\beta x + B\sin\beta x),$$

in which $A = C_1 + C_2$, and $B = i(C_1 - C_2)$, are arbitrary constants, and are both real if C_1, C_2, be taken as conjugate imaginaries.

For example $\frac{d^2y}{dx^2} + 8\frac{dy}{dx} + 25y = 0$

has the auxiliary equation

$$m^2 + 8m + 25 = 0$$

whose roots are $m_1 = -4 + 3i$, $m_2 = -4 - 3i$; hence the solution is

$$y = e^{-4x}(C_1\cos 3x + C_2\sin 3x).$$

Case II. Equal Roots.—If some of the roots of (5) are equal the corresponding terms in (6) coalesce. Thus if $m_1 = m_2$, then $C_1e^{m_1x} + C_2e^{m_2x} = (C_1 + C_2)\ e^{m_1x} = Ce^{m_1x}$, and hence (6) lacks one integration constant of the n necessary for a complete solution. It can be shown, however, that if m_1 be a double root of (5), then $x\,e^{m_1x}$, as well as e^{m_1x}, is a solution of (4). And in general if m_1 is a root of the order p of (5), the equation (4) has the solutions e^{m_1x}, $x\,e^{m_1x}$, $x^2\,e^{m_1x}$, . . . $x^{-p}{}_1e^{m_1x}$.

For example, the equation

$$\frac{d^3y}{dx^3} - 3\frac{d^2y}{dy^2} + 4y = 0$$

has the auxiliary equation

$$m^3 - 3m^2 + 4 = 0$$

whose roots are $-1, 2, 2$. Hence the complete integral is

$$y = C_1 e^{-x} + C_2 e^{2x} + C_3 x e^{2x}.$$

Similarly if the auxiliary of a 4th degree equation be

$$m^4 - 4m^3 + 10m^2 - 12m + 5 = 0$$

the roots are $1, 1, 1 \pm 2i$, and the complete solution is

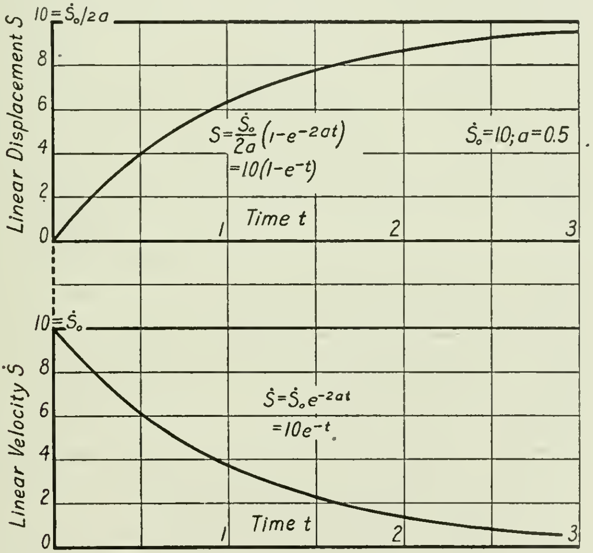
$$y = C_1 e^x + C_2 x e^x + C_3 e^x \cos 2x + C_4 e^x \sin 2x.$$

PART II. FREE OSCILLATIONS.

COMPONENT TERMS OF RECTILINEAR DAMPED HARMONIC MOTION.

Kinematics of Damped Straightaway Motion.—Equation (1′)

FIG. 2.



Damped straightaway motion of a particle subject to a resistance proportional to the velocity.

for damped straightaway motion gives, on integration for s and $\dot{s}$, the general values,

$$s = Ae^{-2at} + B$$
$$\dot{s} = -2aAe^{-2at}$$

in which A and B are constants of integration. And if the initial speed is $\dot{s} = \dot{s}_0$, when $s = 0 = t$, the constants are $A = -B = -\dot{s}_0/2a$.

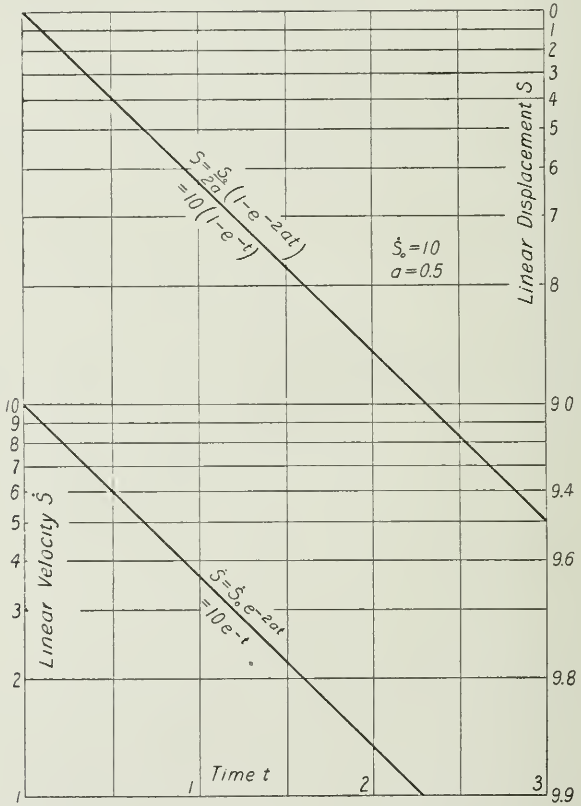
Hence

$$s = \frac{\dot{s}_0}{2a}\left(1 - e^{-2at}\right) \dots\dots (7)$$

$$\dot{s} = \dot{s}_0 e^{-2at} = \dot{s}_0 - 2as \dots\dots (8)$$

As t increases indefinitely e^{-2at} vanishes asymptotically; s approaches the limit $\dot{s}_0/2a$; and the speed $\dot{s}$ vanishes asymptotically.

FIG. 2′.



Damped straightaway motion of a particle subject to a resistance proportional to the velocity.

The motion is a species of *subsidence,* or a disturbance which dies out without oscillation.

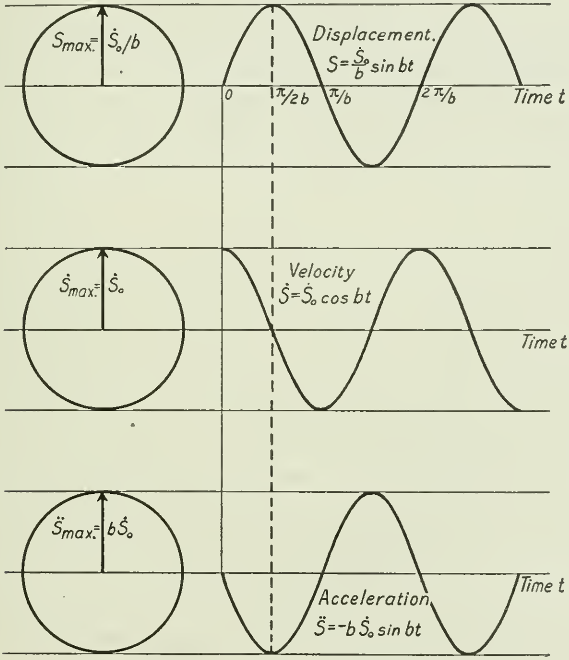
The graphs of (7) and (8), in Fig. 2, and Fig. 2′, illustrate how the travel s, of the particle, asymptotically approaches its limit $\dot{s}_0/2a$, and how similarly the speed dies away in infinite time, as indicated by the exponential factor e^{-2at}. Such factorial expressions go by the general name of "*damping factor.*"

Kinematics of Simple Harmonic Motion.—Equation (2′) for simple harmonic motion gives, on integration for s and $\dot{s}$, the general values

$$s = A \sin bt + B \cos b\,t$$
$$\dot{s} = b\,(A \cos b\,t - B \sin b\,t)$$

in which A and B are constants of integration. If the initial speed is $\dot{s} = \dot{s}_0$, when $s = 0 = t$, the constants are, $B = 0$, $A = \dot{s}_0/b$.

FIG. 3.


$S_{max} = \dot{S}_0/b$
Displacement.
$S = \frac{\dot{S}_0}{b} \sin bt$
0
$\pi/2b$
π/b
$2\pi/b$
Time t
$\dot{S}_{max} = \dot{S}_0$
Velocity
$\dot{S} = \dot{S}_0 \cos bt$
Time t
$\ddot{S}_{max} = b\dot{S}_0$
Acceleration
$\ddot{S} = -b\dot{S}_0 \sin bt$
Time t

Simple harmonic motion, graphical elements of.

Hence

$$s = \frac{\dot{s}_0}{b} \sin b\,t \quad \text{(9)}$$
$$\dot{s} = \dot{s}_0 \cos b\,t \quad \text{(10)}$$
$$\ddot{s} = -\,b\,\dot{s}_0 \sin b\,t \quad \text{(11)}$$

These general equations for the displacement, velocity and acceleration of the oscillating particle at any instant, are plotted as functions of the time in Fig. 3.

(a) *Maxima.*—It appears both from this figure and from the equations that for $b\,t = 0, \pi, 2\pi$, etc., the displacement s, and acceleration s, are 0, while the velocity $\dot{s}$ has its greatest absolute value $\dot{s}_0, -\dot{s}_0, \dot{s}_0$, etc. Also that for $bt = \pi/2, 3\pi/2$, etc., the velocity is null, while the displacement and acceleration have their greatest absolute values; viz., $s_1 = \dot{s}_0/b$, $\ddot{s}_1 = -b\,\dot{s}_0$. The maximum displacement s_1 is called the "*amplitude.*"

(b) *Period and Frequency.*—It is seen also that as $b\,t$ changes by 2π, the quantities $s, \dot{s}, \ddot{s}$, run through a complete to-and-fro cycle, so that the *period* T of such a cycle, or oscillation, is

$$T = 2\,\pi/b \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

That is T is the time of passage of the particle from any point of its path to that point again in the same direction. The *frequency* N of the oscillation is obviously $N = 1/T = b/2\pi$.

Incidentally the force on the particle at any displacement can now be written in terms of the mass and period or frequency. It is, by (2) and (12),

$$F = -\frac{4\,\pi^2}{T^2}\,ms = -\,4\,\pi^2\,N^2\,ms \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

(c) *Phase and Epoch.*—If when $s = 0$ in (9) $bt = \epsilon$, the equation becomes $s = \frac{\dot{s}_0}{b}\sin\,(bt - \epsilon)$. Then $(bt - \epsilon)$ is called the "*phase angle*" or "phase," and ϵ the epoch angle or "*epoch.*" This change of algebraic expression for s would produce in Fig. 3 a shift of the origin along the axis of t.

(d) *Added Motions.*—A number of simple harmonic motions $s_1 = C_1 \sin b\,t$, $s_2 = C_2 \cos b\,t$, etc., having the same period $2\pi/b$, can be imposed simultaneously on a particle, giving it a resultant simple harmonic motion of the same period. This statement is proved in textbooks on mechanics, and is merely recalled here as a reminder that such an expression as $s = (C_1 \sin b\,t + C_2 \cos b\,t)$ is a simple harmonic motion.

(e) *Projected Circular Motion.*—Simple harmonic motion may be represented as the projection, on the diameter of a circle, of the movement of a point speeding uniformly round the circumference. Thus in Fig. 4, if the point p moves with uniform linear speed $\dot{s}_0$, round the circle of radius $\dot{s}_0/b$, its angular speed is b; its angular displacement, or *reference angle,* referred to the horizontal radius, is $b\,t$ in time t; and its vertical displacement, speed and acceleration are obviously as given in (9), (10), (11).

Also the period of a complete cycle clearly is $2\pi/b$, as given in (12). Hence the kinematic properties, so far found algebraically, for simple harmonic motion, can be read from the *reference circle* whose radius is of length equal to the amplitude of said motion.

(f) *Energy of Simple Harmonic Motion.*—For a particle of mass m, at any displacement s, the force F opposing the motion, and the potential energy W, or work done against F during displacement from rest, are respectively

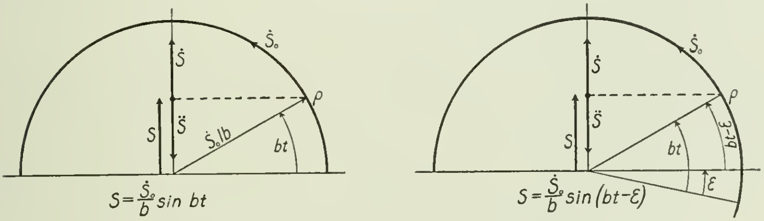
$$F = m\ddot{s} = -m b^2 s,$$

$$W = -\frac{F}{2} s = m b^2 s^2/2 \ldots\ldots (14)$$

since the mean value of the reversed effective force causing the displacement is $-F/2$. But by (9) and (10), $\dot{s}^2 = \dot{s}_o^2 - b^2 s^2$; hence the kinetic energy, $E = m\dot{s}^2/2$, of the particle is

$$E = \frac{m}{2}(\dot{s}_o^2 - b^2 s^2) \ldots\ldots (15)$$

FIG. 4.



Motion with zero epoch

Motion with epoch-ε

Simple harmonic motion as the projection of the uniform motion of a point on a reference circle.

Hence the total energy, kinetic and potential, of the particle is

$$E + W = m\,\dot{s}_o^2/2 = \text{constant}, \ldots\ldots (16)$$

The mean potential energy throughout the period, $T = 2\pi/b$, is $W_m = \frac{1}{T}\int_0^T W\,dt$, which on writing, from (14) and (9), $W = b^2 m\,s^2/2 = \frac{m\,\dot{s}_o^2}{2}\sin^2 bt$, and integrating, gives

$$W_m = m\,\dot{s}_o^2/4, \ldots\ldots (17)$$

or half the total energy. So also the mean kinetic energy is $m\,\dot{s}_o/4$. Both these and the total energy vary as $\dot{s}_o^2$; also as the square of the amplitude or maximum displacement, which was shown to be $s_1 = \dot{s}_o/b$.

Reversed Simple Harmonic Motion.—If in equation (2) the sign of b^2 be reversed, that is if the force and acceleration be directed away from the point of equilibrium, the equation of motion becomes on integration

$$s = A\,e^{bt} + B\,e^{-bt}$$

$$\dot{s} = A\,b\,e^{bt} - B\,b\,e^{-bt}$$

The first of these equations shows that the space increases indefinitely with the time, and always in one direction, that is without oscillation; the second shows that the speed increases indefinitely.

A motion that increases without oscillation is called a "*divergence.*" The displacement may increase indefinitely or it may asymptotically approach a limit. In the latter case it also answers the definition of a subsidence.

KINEMATICS OF RECTILINEAR DAMPED HARMONIC MOTION.

The General Integral.—Equation (3) for damped harmonic motion gives, on integration for s and $\dot{s}$, the general values

$$s = Ae^{\alpha t} + B\,e^{\beta t}$$

$$\dot{s} = A\alpha\,e^{t} + B\,\beta\,e^{\beta t}$$

in which A and B are constants of integration, and the roots of the auxiliary equation are

$$\left.\begin{aligned}\alpha &= -\,a + \sqrt{a^2 - b^2} = -\,a + r_1\\ \beta &= -\,a - \sqrt{a^2 - b^2} = -\,a - r_1\end{aligned}\right\}\quad\text{.....................}\ (18)$$

If $\dot{s} = \dot{s}_o$ when $s = o = t$, the constants are $A = \dot{s}_o/2r_1$, $B = -\dot{s}_o/2\,r_1$. Hence

$$s = \frac{\dot{s}_o}{2r_1}\,(e^{\alpha t} - e^{\beta t})\ \text{..................................}\ (19)$$

$$\dot{s} = \frac{\dot{s}_o}{2r_1}\,(\alpha\,e^{\alpha t} - \beta\,e^{\beta t})\ \text{............................}\ (20)$$

are the general values of the displacement and speed of the oscillating point in terms of the time and given coefficients a, b. The solution takes three forms according as a is less than, equal to, or greater than b; viz., as $r_1, = \sqrt{a^2 - b^2}$, is imaginary, zero or real.

Case I: $a<b$; Motion Periodic.—When r_1 is imaginary write $r_1 = ir$, where $r = \sqrt{b^2 - a^2}$, and (19) becomes, on using the values of α, β, in (18),

$$s = \frac{s_o}{2\,i\,r}\,e^{-at}(e^{irt} - e^{-irt}).$$

Now substituting in this equation Euler's values,

$$e^{irt} = \cos rt + i \sin rt ,$$

$$e^{-irt} = \cos rt - i \sin rt ,$$

the imaginary i cancels out, and the displacement and speed are found in the form,

$$s = \frac{s_0}{r} e^{-at} \sin rt, \quad \ldots\ldots (21)$$

$$\dot{s} = \dot{s}_0 e^{-at} \left(\cos rt - \frac{a}{r} \sin rt\right). \quad \ldots\ldots (22)$$

$$= \frac{\dot{s}_0}{\cos \varepsilon} e^{-at} \cos (rt + \varepsilon), \text{ where } \frac{a}{r} = \tan \varepsilon ,$$

$$= \frac{\dot{s}_0 b}{r} e^{-at} \cos (rt + \varepsilon)$$

(a) *Plot of Factors and Product.*—The right-hand members of (21) and (22) consist each of the product of two factors, an exponential factor e^{-at}, and a harmonic factor. In Fig. 5 these factors and their product are plotted as functions of the time. The sketches show, what is clear from the symbolic expressions, that e^{-at} decreases asymptotically to zero as the time increases indefinitely, while each harmonic factor represents a curve of constant amplitude and pitch. The ordinate of the damped harmonic curve is the product of the coincident ordinates of the component curves, *i.e.*, the exponential and the simple harmonic, and hence dies away in an oscillatory manner to zero as the time increases indefinitely. The amplitude of the simple harmonic motion in (21) is $\dot{s}_0/r$, which when $a = o$ is $\dot{s}_0/b$, as given in (9) for undamped motion. Each amplitude is the radius of the corresponding reference circle.

(b) *Period and Reference Angle.*—From equations (21) and (22) can be found the time of describing each stroke of the damped harmonic, and the corresponding value of the reference angle $r\ t$. Starting with $s = o = t$, it appears from (21) that $s = o$ again in the successive times given by $rt = \pi, 2\pi, 3\pi \ \ldots \ n\pi$; that is the time of each out-and-back stroke is

$$T^{1} = \pi/r. \quad \ldots\ldots (23)$$

or the whole period is $T = 2\pi/r$. Also the time T^{11} for any single outstroke to where $s = o$ is given by (22) in the form $\cos(rT^{11} + \epsilon) = o$, or $rT^{11} + \epsilon = \frac{\pi}{2}$; whence

$$T^{11} = \frac{1}{r}\left(\frac{\pi}{2} - \varepsilon\right) \quad \ldots\ldots (24)$$

Multiplying (23) and (24) by r gives the reference angles. Hence from these equations the chief elements of displacement and time can be summarized as follows:

TABLE I.

Period of Harmonic Movements.

Movement	Duration t.	Reference angle rt
Out stroke	$\frac{1}{r}\left(\frac{\pi}{2}-\varepsilon\right)$	$\frac{\pi}{2}-\varepsilon$
Back stroke	$\frac{1}{r}\left(\frac{\pi}{2}+\varepsilon\right)$	$\frac{\pi}{2}+\varepsilon$
Out-and-back stroke	$\frac{\pi}{r}$	π
Complete cross stroke	$\frac{\pi}{r}$	π
Complete double vibration	$\frac{2\pi}{r}=T=\frac{2\pi}{\sqrt{b^2-a^2}}$	2π
Simple harmonic vibration	$2\pi/b=T_0$	2π
Ratio of last two periods $T/T_0=b/\sqrt{b^2-a^2}$		

From the foregoing paragraph it appears that damped, like undamped harmonic oscillations, are isochronous, and that their period is to that of the undamped ones in the ratio $b/\sqrt{b^2-a^2}$. This ratio equals unity when $a=0$; and is infinity when $a=b$, or when the motion just becomes aperiodic.

(c) *Maxima of Displacement and Speed.*—By (21) for s maximum $\dot{s}=0$, giving $rt=\frac{\pi}{2}+n\pi-\epsilon$; hence $s=\frac{\dot{s}_0}{r}\,e^{-at}\cos\epsilon=\frac{\dot{s}_0}{b}$ e^{-at}. For $\dot{s}$ maximum the reference angle is $rt=(n+1)\pi-2\epsilon$; hence $\dot{s}=\dot{s}_0e^{-at}$. Again since the multipliers of e^{-at} in (21) and (22) remain unchanged as t increases by any number of whole periods, or by $n\,T$, the ratio of the nth + 1 maximum to the first is $s_{n+1}/s_1=e^{-n\,aT}=\dot{s}_n/\dot{s}_0$. Hence the graphs of the equations

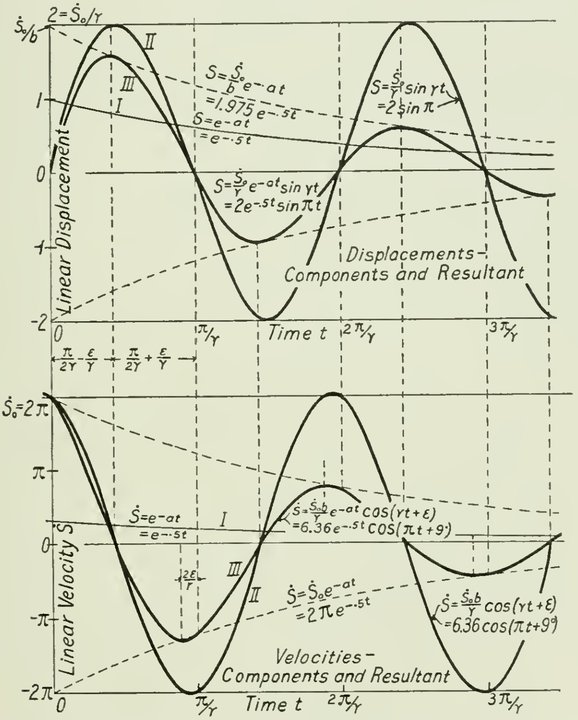
$$s=s_1e^{-at'} \qquad (25')$$

$$=\frac{\dot{s}_0}{b}\,e^{-at} \qquad (25)$$

$$\dot{s}=\dot{s}_0\,e^{-at} \qquad (26)$$

where t' is the value of t for the first maximum s_1, are curves passing through all the maxima points respectively of s and $\dot{s}$, as shown in Fig. 5; for t being continuous assumes in turn all the discreet values of $n\,T$, whereupon s and $\dot{s}$ assume all the values of s_n and $\dot{s}_n$ respectively. It may be noted from (25) and (26) that the successive maxima of each curve (21) and (22) form a geometric series whose ratio is e^{-aT}, or that the nth amplitude is $s_n = \frac{\dot{s}_0}{b} e^{-anT}$. It is worth observing also that (25) and (26)

FIG. 5.



Displacement and speed in the periodic damped harmonic oscillation. I and II are components of III. The exponential curves cut the crests of the damped harmonic curves.

represent curves of discreet points, *i.e.*, wave tops, when T is substituted for t. On semilogarithmic paper (25) and (26) plot as straight lines, whose slopes are equal to a, as shown in Fig. 6.

For interpreting stability equations it is useful to note from (25) that $s = s_1/2$ when $a\,t = \log_e s_1/s = \log_e 2 = 0.693$; that is, the time of damping to one-half amplitude is

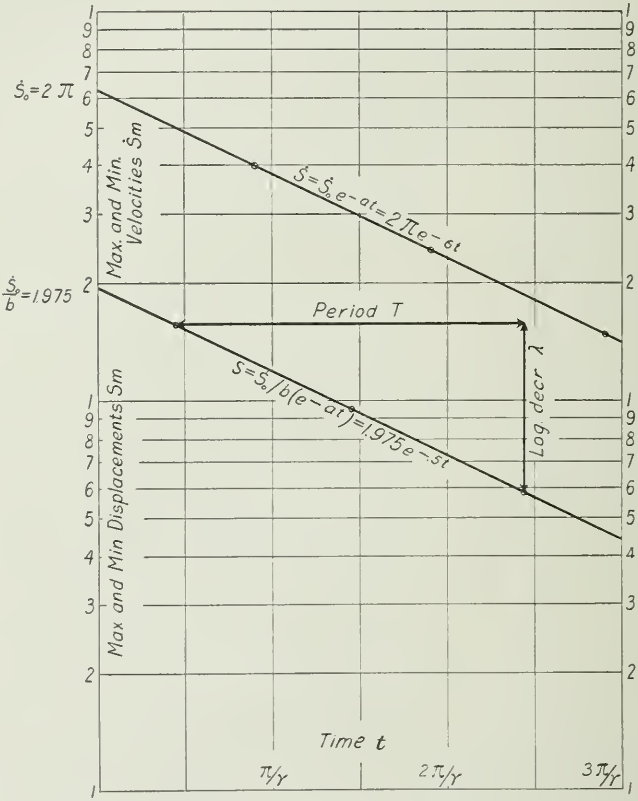
$$t = 0.693/a \quad \text{...} \quad (27)$$

(d) *Logarithmic Decrement.*—From (25) one derives

$$\log s = \log s_1 - a\,t \qquad (28)$$

a linear equation in t, whose straight-line graph, as in Fig. 6, is useful in plotting oscillation data to show the rate of decline of the amplitude. In general the decrement of log s, or $\log s_1 - \log s = a\,t = \log \frac{s_1}{s}$, is directly proportional to the time, and therefore the same for successive periods T. In particular the *natural* logarithm of the ratio of any maximum to the next succeeding is called the "*logarithmic decrement.*" It is the constant decrease in the logarithm of the amplitude which occurs during each whole

FIG. 6.



Maxima and minima of displacement and speed in periodic damped harmonic oscillation. Circles mark the maxima and minima.

period $2\pi/r$, and may be written in the forms,

$$\lambda = \left| \begin{array}{l} \frac{1}{n} \log\left(\frac{s_1}{s_{n+1}}\right) \\ \log\frac{s_n}{s_{n+1}} = \log e^{a\,T} = a\,T = \frac{2\,a\pi}{r} = \frac{2\,a\pi}{\sqrt{b^2-a^2}} \\ \log s_n - \log s_{n+1} = \triangle \log s_n = \frac{\triangle\, s_n}{s_n} = \left(\frac{s_n - s_{n+1},}{s_n}\right. \\ \qquad\qquad\qquad\qquad\qquad\qquad \text{for feeble damping)} \end{array} \right. \qquad (29)$$

The form $\Delta s_n/s_n$ is the fractional, or "percentage," damping in one complete oscillation.

Obviously the logarithmic decrement of the velocity "amplitude," as pictured in Figs. 5 and 6, could be treated in an analogous manner.

(e) *Ratio of Damped and Undamped Periods.*—By Table I the ratio of the periods of the damped and undamped harmonic oscillations is $T/T_o = \mathrm{b}/\sqrt{b^2-a^2} = 1 + \frac{1}{2}\;\frac{a^2}{b^2}\; + \ldots$, T_o being the undamped period. By (29) when a/b is small, $a/b = \lambda/2\pi$. Hence

$$T/T_o = 1 + \lambda^2/8\pi^2 = 1 + 0.01268\lambda^2 \qquad (30)$$

For example, if in one period the relative decrease of amplitude is, $\frac{s_n - s_n + 1}{s_n} = \lambda = 1/10$, the ratio of the damped and undamped periods is $T/T_o = 1.0001268$. This shows that when the damping is so great that successive maxima in the harmonic curve differ by 1/10, the period of the damped vibration is only about 1/8000 longer than the free period.

(f) *Coefficients in the Equation of Damped Harmonic Motion.*—If the time $n\;T$, of n successive oscillations, and the corresponding change of amplitude be observed, the values of a and b can be computed from the formulas already derived. Thus from $\lambda = a\;T$, and $T = 2\pi/\sqrt{b^2-a^2}$, there follow

$$a = n\lambda/n\;T \qquad (31)$$

$$b = \sqrt{\lambda^2 + 4\pi^2}/T \qquad (32)$$

in which a is the slope and $n\lambda$, $n\;T$, the coördinates of the graph of the oscillation data plotted as in Fig. 6.

For a/b small, (32) gives $b \propto 1/T$, on recalling that $a/b = \lambda/2\pi$; and (31) taken with (30) gives $a \propto \lambda$. That is, for a moderately damped oscillation the elastic coefficient is a function chiefly of the observed period; the damping coefficient chiefly of the rate of decay. Both are still acceleration coefficients, as illustrated in Fig. 1. The corresponding frictional and elastic forces, as given in (1) and (2), are respectively $-2\,m\,a\,\dot{s}$, $-\,m\,b^2\,s$, m being the mass of the oscillating particle.

Case II: $a = b$; Critical Periodicity.—For the reason given in the mathematical preamble, the solution (19) and (20) fail when the roots of (3) are equal; but this on direct integration gives, if $\dot{s} = \dot{s}_o$, when $s = o = t$,

$$s = \dot{s}_o\, t\, e^{-at} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (33)$$

$$\dot{s} = \dot{s}_o\, e^{-at}\,(1 - a\,t) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (34)$$

These values of the displacement and speed are plotted as functions of the time in Fig. 7. Starting from zero, s increases till $\dot{s} = o$, $t = 1/a$, when it attains its maximum value $s_m = \dot{s}_o/ae = 0.368\ \dot{s}_o/a$; then diminishes asymptotically to zero in infinite time. Hence the period is infinite, and the motion is called "*aperiodic.*" The speed starting with the value $\dot{s}_o$, becomes zero when $t = 1/a$; becomes a minimum $\dot{s}_m = -\dot{s}_o/e^2 = -0.135\ \dot{s}_o$, in time $t = 2/a$; then dies out asymptotically to zero in infinite time. After its first reversal each of the graphs represents a subsidence, the one of displacement, the other of velocity. The sinusoids of Fig. 6 become straight lines in Fig. 7.

Case III: $a > b$; Aperiodic Motion.—The general values (19), (20), of the displacement and speed, when $a > b$, can, by use of (18), be reduced directly to

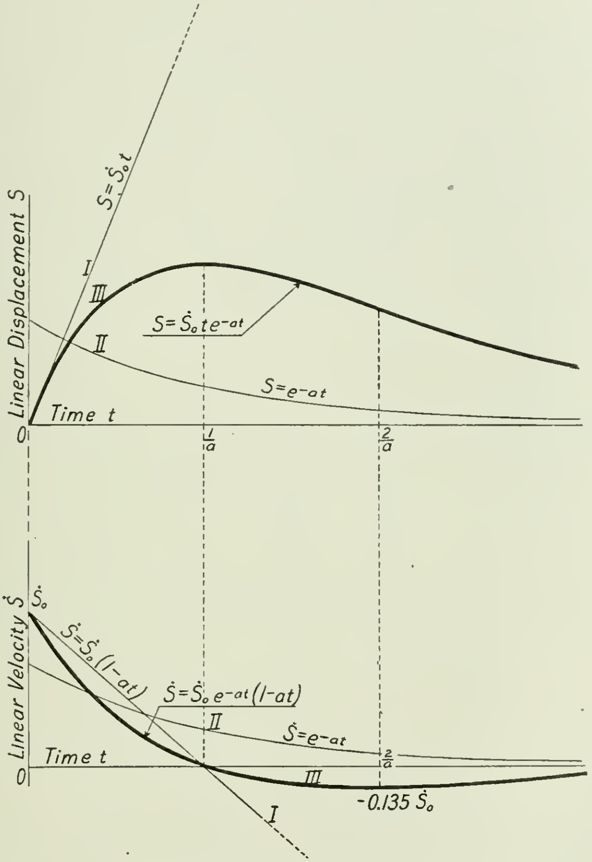
$$s = \frac{\dot{s}_o}{2\,r_1}\, e^{-at}\, (e^{r_1 t} - e^{-r_1 t}) \dots\dots\dots\dots\dots\dots\dots\dots (35)$$

$$s = \frac{\dot{s}_o}{2\,r_1}\, e^{-at} \Big[\, (-\,a + r_1)\, e^{r_1 t} + (a + r_1)\, e^{-r_1 t} \,\Big] \dots\dots (36)$$

The graphs of these equations simulate those of Fig. 7. Starting from zero, s increases till $\dot{s} = o$, $t = \frac{1}{2\,r_1} \log \frac{a + r_1}{a - r_1}$, when it attains its maximum value s_m, found by putting this value of t in (35); then diminishes asymptotically to zero in infinite time. The motion is therefore aperiodic. The speed, starting with the value

$\dot{s}_0$, falls to zero at the time t just found; changes sign and becomes a minimum when t equals twice this value; then dies out asymptotically in infinite time. After its first reversal each of the graphs for Case III, as for Case II, represents a subsidence. For $b = o$, (35) and (36) are easily seen to become (7) and (8) respectively, since then $r_1 = \sqrt{a^2 - b^2} = a$.

FIG. 7.



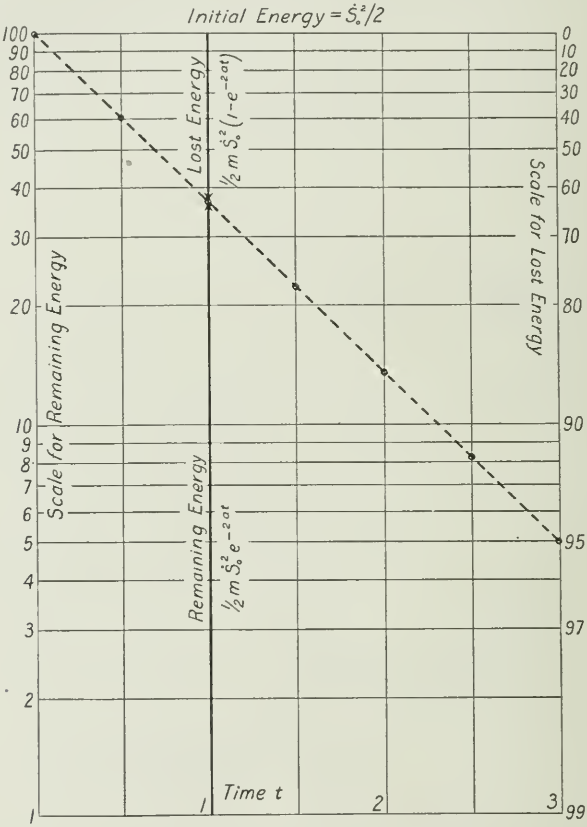
Displacement and speed in a periodic damped harmonic oscillation. I and II are components of III.

Influence of a on Type of Motion.—The foregoing text shows that for $a = o$, the motion is sinusoidal; for $a < b$, it is oscillatory with decaying amplitude; for $a \geqq b$ it is aperiodic, *i.e.*, dies away without oscillation.

ENERGY OF DAMPED HARMONIC MOTION.

General Equation of Energy.—Except for a friction term, the energy expression for damped harmonic motion is like that for simple harmonic motion. If the particle m starts at $s = o = t$, with speed $\dot s_o$, its initial energy is $m\,\dot s_o^2/2$; at any later time its kinetic energy is $E = m\dot s^2/2$; its potential energy is $W = m\,b^2 s^2/2$, by (14); and their sum equals the initial energy less that consumed by the friction $f = -2m\,a\,\dot s$. Since the rate of frictional loss is $f\,\dot s\,d\,t = -2\,m\,a\,\dot s^2\,d\,t$, the total energy at any time t is

FIG. 8.



Energy in periodic damped harmonic oscillation.

$$E + W = m\ \dot s_o^2/2 - 2\,m\,a\int_0^t \dot s^2 d\,t \quad\ldots\ldots\ldots\ldots(37)$$

which has the form of (16) except for the last term.

Integral of Lost Energy.—The friction term can be integrated for any portion of the movement, since $\dot{s}$ has been found in terms of t, in earlier parts of the text. For any single stroke the lost energy can be found without integration, since at mid-stroke the total energy is $m\dot{s}^2/2$; and at the end of the stroke it is $m\ b\ s^2/2$; while s and $\dot{s}$ are given by (25) and (26).

For example, if the motion is periodic, the energy at mid-stroke and full stroke, respectively, is

$$E = \frac{1}{2}\ m\,\dot{s}^2 = \frac{1}{2}\ m\,\dot{s}_0{}^2 e^{-2at},\ W = \frac{1}{2}\ m\,b^2 s^2 = \frac{1}{2}\ m\,\dot{s}_0{}^2 e^{-2at}$$

and these values plotted against time, on semilogarithmic paper, lie on a straight line, as in Fig. 8. For the particular values of a/b that make $\cos \epsilon = 1$ in (25), the graph in Fig. 8 delineates at every point the value of the integral in (37); but otherwise only at the marked points, for which the energy is all kinetic or all potential.

INFLUENCE OF MASS IN DAMPED HARMONIC MOTION.

Kinematic Equation Containing Mass Explicitly.—The general equation (3) contains implicitly the mass m, of the particle, and may be rewritten in the form

$$\ddot{s} + \frac{2a_1}{m}\,\dot{s} + \frac{b_1{}^2}{m}\,s = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (38)$$

in which all the terms are still accelerations. The following definitions may be useful:

$\frac{2a_1}{m} \equiv$ coefficient of damping acceleration,

$\frac{2a_1\dot{s}}{m} \equiv$ damping acceleration,

$2a_1 \equiv$ coefficient of damping force,

$2a_1\dot{s} \equiv$ damping force.

Kinematic Effect of Mass.—The effect of m in modulating the motion can now be seen by placing these two coefficients, respectively, in place of $2a$ and b^2 in the previous equations of the text. Thus, if they be substituted in Table I, they show that increase of m prolongs the periods $2\pi/b$, $2\pi b/\sqrt{b^2 - a^2}$, respectively, of undamped and damped motions. Similarly m is seen to diminish the rate of damping $c\frac{-a_1t}{m}$, and the rate of dissipation of energy $2\ m\ \frac{a_1}{m}\dot{s}^2$ where $\dot{s} \propto e^{-\frac{a_1}{m}t}$, as seen by (22).

APPLICATION TO ANGULAR MOTION.

Equation of Angular Damped Harmonic Motion.—All the foregoing equations can be directly applied to the vibrations of a body about a fixed axis, usually taken as the principal centroidal axis, if m be replaced by I, the moment of inertia of the body for that axis, and if s, $\dot{s}$, $\ddot{s}$ be replaced by the corresponding angular values. Thus the angular analogue of (38) may be written

$$\theta + \frac{2\mu_1}{I}\theta + \frac{K_1{}^2}{I}\theta = o \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (39)$$

and the coefficients of $\dot{\theta}$ and θ may be respectively substituted for $2a$ and b^2 in the equations (1) to (37), to derive the corresponding expressions for angular vibration. For example, the period $T = 2\pi/b$, for undamped motion, becomes

$$T = 2\pi\sqrt{I} / K_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (40)$$

while a similar expression is found for damped motion.

Formula for Moment of Inertia in Torsional Vibration.—Equation (40) is sometimes used to determine I for a model. If T is observed in a vibration test, and the elastic coefficient K_1 is known from a torsion test, I can be computed directly from (40). It may be recalled that in such torsion test the torsional moment M, and the ensuing displacement θ, in radians, are measured to determine $K_1 = M/\theta$.

If K_1 is not supplied, T_1 may be observed in a second vibration test with the same model having an added moment of inertia I_1, and will evidently satisfy the formula $T^1 = 2\pi\sqrt{I + I_1} / K_1$. From this and (40) one derives

$$I = I_1 \frac{T^2}{T_1{}^2 - T^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (41)$$

which can be used to find I from two vibration tests, when the elasticity of the spring is unknown.

A similar operation may be used to determine I when the motion is damped.

PART III. FORCED OSCILLATIONS.

KINEMATICS OF RECTILINEAR FORCED OSCILLATIONS.

The foregoing text treats briefly the theory of the free rectilinear oscillation of a particle both undamped and damped, and indicates a like treatment for the theory of oscillation of a rigid body about a fixed axis. In closing, attention may be given also to a simple case of a forced oscillation superposed upon the free.

Equation of Forced Oscillation and Resultant Oscillation.—When a particle is performing free vibrations as represented by (3), let it be subjected to a single additional acceleration from without, parallel to the given motion, and a continuous function of the time. This latter may have any one of numerous forms. For the present let the applied acceleration be taken as a simple harmonic function of the time; so that (3) becomes

$$\ddot{s} + 2\,a\,\dot{s} + b^2 s = h \sin \omega\, t \qquad (42)$$

The complete solution of this equation can be written as the sum of its complementary function (19), and its particular integral, which is easily shown to have the form

$$s = \frac{h}{\sqrt{(b^2 - \omega^2)^2 + 4\epsilon^2\omega^2}} \sin\,(\omega\, t - \varepsilon) \qquad (43)$$

$$= \frac{h \sin \varepsilon}{2\,a\omega} \sin\,(\omega\, t - \varepsilon) \qquad (43')$$

where

$$\tan \varepsilon = 2\,a\,\omega/(\,b^2 - \omega^2) \qquad (44)$$

And if the complementary function has the particular form (21), for a periodic oscillation, the complete integral is

$$s = \frac{\dot{s}_o}{r}\, e^{-a\,t} \sin\, r\,t + \frac{h}{\sqrt{(b^2 - \omega^2)^2 + 4a^2\omega^2}} \sin\,(\omega\, t - \varepsilon) \qquad (45)$$

where the last term represents the forced oscillation, which is superposed upon the free one given by the other term; and ϵ is the phase difference between the applied acceleration and the consequent oscillation.

Magnitude of the Resultant Oscillation.—Since the right member of (45) has only t variable, its first term, if $a \neq o$, is graphically represented by a damped, its second term by an undamped, sine curve; and hence their resultant gradually becomes an undamped sine curve represented by the second term. That is, the free vibration gradually dies out, and the oscillation of the particle has for steady motion that due to the applied acceleration only. But in the ideal case when $a = o$, the motion is the resultant of a permanent free simple harmonic oscillation added to a forced oscillation, also assumed permanent, whose peculiarities are still to be examined. In general the periods $2\pi/r$ and $2\pi/\omega$, of the two motions, and their frequencies $r/2\pi$, $\omega/2\pi$, are different.

Period and Magnitude of the Forced Oscillation.—The forced oscillation (43) has the same period $2\pi/\omega$ as the applied acceleration, and contains four arbitrary parameters, h, a, b, ω, in the expression for its amplitude. This latter varies directly as h, the coefficient of intensity of the applied acceleration, and inversely as $(b^2 - \omega^2)^2 + 4\ a^2\omega^2$, which has three arbitrary parameters. For a given value of h, therefore, the amplitude will be small when this binomial is large, and *vice versa.*

Conditions Making Forced Oscillation Small.—The condition that, for a given intensity h, the forced vibration shall be feeble is that $(b^1 - \omega^2)^2 + 4\ a^2\omega^2$ be large, where a, b and ω are positive. This can occur when $b - \omega$ is large; that is, when there is a large difference between the frequencies of the undamped free oscillation and the applied acceleration; also when a ω is large, which may be due to large damping or to high frequency.

Conditions Making Forced Oscillation Large.—The general condition that the forced oscillation shall be large is that $(b^2 - \omega^2)^2 + 4\ a^2\omega^2$ be small, which means that both $b - \omega$ and $a\omega$ are small. As $b - \omega$ tends toward zero $\tan\epsilon, = 2a\omega/(b^2 - \omega^2)$, tends toward $\pm\infty$, that is ϵ approaches $\pi/2$ from either side, according as b is greater or less than ω. The condition $a\omega$ small indicates that, even with considerable damping, the oscillation can be large if the frequency, $\omega/2\pi$, of the applied acceleration is sufficiently small, while nearly equalling the frequency, b/π, of the undamped free oscillation.

For $a = o$, if $b - \omega \neq o$, $\tan\epsilon = o$, and the forced oscillation (43) becomes $s = \frac{h}{b^2 - \omega^2} \sin\omega t$, showing that the phases of the motion and of the applied acceleration agree in sign if $b > \omega$, and *vice versa.* But if $b - \omega = o$, $\tan\epsilon = o/o$, and the integral of (42) for this special case can better be written

$$s = \frac{-h\,t}{2\,\omega}\cos\omega\,t \qquad \text{.................................(46)}$$

which indicates a divergent harmonic motion whose period is that of the undamped free oscillation, and whose amplitude $h\ t/2\ \omega$ increases directly as the time, having infinity as its "steady" value. For large values of t the speed of the particle, $\dot{s} = \frac{h\,t}{2}\sin\omega t$, has the same phase as the applied acceleration $h \sin \omega t$. This case is treated somewhat differently by Lord Rayleigh, in his "Theory of Sound," § 41, which is recommended for present reference, and from which is taken the expression (51) below.

Special Forms of the General Equation.—The general equation (42) may be given various interesting special forms by assigning certain particular values to the constant coefficients, a, b, h, ω. Thus if a alone is zero the equation is that of a forced undamped harmonic oscillation $\dot{s} - b^2 s = h \sin \omega t$, an interesting case of which is given in (46). Again, if in (42) $h \sin \omega t$ is constant, the equation is that of a damped harmonic oscillation with a constant disturbing force. In this case, which is of some interest in aeronautic experiments, (42) becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = c \qquad (47)$$

whose solution is

$$s = s_1 + c/b^2 \qquad (48)$$

where s_1 is the solution of (3).

It may be recalled that, for a free damped periodic motion, the plot of s_{max} on semilogarithmic paper is a dotted straight line, as in Fig. 6. The form of (48) shows that the graph ceases to be straight when a constant disturbing acceleration occurs.

More General Forced Oscillation.—By Fourier's theorem any single-valued periodic function $f(t)$, of period $T = 2\pi/\omega$, can be expanded, between definite limits of the variable, in a series of the form

$$f(t) = h_o + h_1 \sin(\omega t + \varepsilon_1) + h_2 \sin(\omega \cdot 2t + \varepsilon_2)$$
$$+ h_3 \sin(\omega \cdot 3t + \varepsilon_3) + \ldots \qquad (49)$$

Hence if an applied acceleration of this form be substituted for the second member of (42), the equation of the forced oscillation of the particle becomes

$$\ddot{s} + 2a\dot{s} + b^2 s = \Sigma_o^n h_n \sin(\omega \cdot nt + \varepsilon_n) \qquad (50)$$

The integral of this takes the form of (45), but with its last term summational. Thus the rectilinear motion of the particle consists of a damped free oscillation, of period $2\pi/r$, upon which is superposed a complex harmonic motion composed of n forced oscillations of periods $T, T/2, T/3, \ldots T/n$, and phases $\epsilon_1, \epsilon_2, \ldots \epsilon_n$.

ENERGY OF FORCED OSCILLATIONS.

The kinetic energy of the forced oscillation, whether damped or undamped, is proportional to $\dot{s}^2$. For the damped one (43′) gives, if the speed is $\dot{s}_0$, when $s = o$,

$$\text{Energy} \propto \dot{s}^2_0 \propto \sin^2 \varepsilon \qquad \text{(51)}$$

This is a maximum when $\epsilon = \pi/2$, or by (44), when $\omega = b$. That is, the forced oscillation attains its greatest kinetic energy when the period of the applied acceleration equals the natural period of the undamped free oscillation. For the undamped forced oscillation, when $\omega = b$, the kinetic energy, as shown by (46), increases indefinitely with the time.

APPLICATION TO ANGULAR MOTION.

The foregoing equations for the rectilinear forced oscillations of a particle can be applied to the motion of a rigid body oscillating about a fixed axis, in the manner already explained for free oscillations.

The Anomaly of the Nickel-Steels. C. E. GUILLAUME, Director of the International Bureau of Weights and Measures, Sevres. (*Proc. Phys. Soc. London,* August 15, 1920.)—In this lecture the distinguished author, to whom the Nobel Prize in Physics for 1920 was awarded, traces the course of the investigations which led to the discovery of the alloy invar. This name is applied to alloys of steel and nickel in which the latter metal enters to the extent of about 35.6 per cent. The characteristic of invar is its low coefficient of linear expansion, .00000119.

From a scientific point of view the new alloy has especially proved its worth in the measurement of geodetic bases. The employment of invar wires scarcely changing their length with temperature has wonderfully facilitated the accurate determination of lengths on the earth's surface. The number of requisite observers is reduced to one-fifth of the previous quota, the time expended is only one-tenth as much, while the expense falls to 2 per cent. of the former amount. In addition it is possible to work on terrain where the older type of apparatus could not have been set up.

Additional applications of nickel-steel alloys are: (*a*) To compensate the pendulums of clocks for temperature changes; (*b*) to render constant the rate of watches. When the balance-wheel is made of only one metal a nickel-steel spring keeps the daily gain or loss very small. (*c*) For the mountings of glass and for leading-in wires to incandescent lamps. An alloy for these purposes is selected with the same expansion coefficient as the glass in question.

G. F. S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NOTES ON SMALL-FLOW METERS FOR AIR, ESPECIALLY ORIFICE METERS.[1]

By Edgar Buckingham.

[ABSTRACT.]

For small-orifice meters the thickness of the orifice plate should be from one to two times the diameter of the orifice, and the entrance should be smooth and well rounded, *i.e.*, trumpet shaped.

The "theoretical" discharge rate of dry air through such an orifice of diameter D mm. is

$$V\text{ (litres/min)} = 2.12\, BD^2\sqrt{T^\circ C} \qquad (1)$$

where V = the volume measured at the initial pressure and temperature,

$$T = \text{the absolute temperature before the orifice}$$
$$B = \sqrt{r^{10/7} - r^{12/7}} \qquad (2)$$

and

$r = p_1/p$ = the ratio of the back to the initial pressure. If V_0 is this same volume reduced to the ice point and 1 atmosphere, we have

$$V_0\text{(litres/min)} = 0.761\, BD^2 \frac{p}{\sqrt{T^\circ C}} \qquad (3)$$

where p = the initial absolute pressure in mm. of mercury.

Actual discharge rates are a few per cent. smaller than theoretical. The discharge coefficient (actual/theoretical) cannot be predicted accurately for small orifices, and experimental standardization is necessary; but the formulas give approximate results (a little too high) and may be used for selecting or designing an orifice to give a certain discharge under a certain suction head.

If the initial pressure is one standard atmosphere and the air is drawn through by a suction head of h cm. of water, the pressure ratio r to be used in equation (2) is $r = (1034 - h)/1034$. Under these circumstances we have the value of B shown in the following table. The values of V are computed from (1) for a 1-mm. hole, an initial temperature at 18° C., and an initial pressure of 760 mm. Hg.

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* Communicated by the Director.

[1] Technologic Paper No. 183.

h	*r*	*B*	*V*
80	0.9226	0.1424	5.144
60	.9421	.1247	4.505
40	.9613	.1029	3.719
30	.9710	.0896	3.238
20	.9807	.0736	2.658
15	.9855	.0639	2.313
10	.9903	.0523	1.889
7	.9932	.0438	1.583
4	.9961	.0332	1.199
2	.9981	.0235	0.848
1	.9990	.0166	.600
0.5	.9995	.0118	.424

Moist air will act nearly like dry unless condensation occurs in the walls of the orifice. When this occurs with small orifices the discharge rate is irregular, and the air should be dried or the orifice warmed.

The diameter of the pipe in which the orifice plate forms a diaphragm should be at least four times the diameter of the orifice, so as to eliminate the effect of the " speed of approach."

Sharp-edged orifices may be used, but they need more complete standardization, because the discharge coefficient varies with the value of *r*.

Capillary tubes may be used to furnish the required resistance to flow, but they are likely to clog. For accurate work they must also be water jacketed if used below the critical speed, because of the change of viscosity of air with temperature. If such a tube is standardized below its critical speed, the standardization must not be used for speeds above the critical, and *vice versa*.

THE PRESENT STATUS OF THE CONSTANTS AND VERIFICATION OF THE LAWS OF THERMAL RADIATION OF A UNIFORMLY HEATED ENCLOSURE.[2]

By W. W. Coblentz.

[ABSTRACT.]

AN examination is made of the instruments, methods, and experimental data pertaining to various determinations of the constant, σ, of total radiation and the constant, *c*, of spectral radiation

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[2] Scientific Paper No. 406.

of a black body. After making obvious corrections for reflection from the receiver and for atmospheric absorption, the determinations of various experimenters are in close agreement, giving a value of $\sigma = 5.72 \times 10^{-5}$ ergs, and $c = 14320$ micron degrees.

GYPSUM—PROPERTIES, DEFINITIONS AND USES.[3]

[ABSTRACT.]

OWING to the rapid growth of the gypsum industry, the nomenclature has not been standardized. A brief description of the various gypsum products will tend to fix their names.

Gypsum is a soft white rock, usually occurring in beds. Other varieties of the same material are known as gypsite and alabaster. It is of common occurrence throughout the United States. Chemically it is a calcium sulphate combined with water. Anhydrite is a variety which contains no water.

Raw gypsum is used for the manufacture of Portland cement and as a fertilizer.

Calcined gypsum is made by heating raw gypsum in a kettle until the first evolution of water has ceased. It contains one-fourth as much water as the raw material. This product is frequently known as plaster of Paris and is used either as such or as the basic ingredient for the manufacture of wall plaster, potters' plaster, dental plaster, etc. Large quantities of it are used in the manufacture of Portland cement, plate glass, and cold-water paints.

When calcined gypsum is mixed with water, it sets to form a hard mass. The time required for this reaction can be varied at will by the addition of suitable retarders or accelerators.

Neat gypsum plaster is calcined gypsum to which has been added some material (such as hydrated lime) to improve its working quality, and the proper amount of retarder. Gypsum sanded plasters are mixed with sand ready for use. Any of these plasters may or may not be " fibred " with either hair or wood fibre. And a special wood-fibred gypsum plaster is made to be used without sand.

Gypsum plasters have excellent fire-resistive ability.

The raw gypsum can be heated until all of the water is given off. The product so formed sets more quickly than calcined gypsum. It is not marketed, but is used at the factory to make such products as gypsum tile, gypsum plaster board, gypsum wall board, etc.

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[3] Circular No: 108.

Further heating of the raw gypsum forms a material which sets very slowly. An accelerated variety of this is marketed as Keene's cement.

Gypsum tiles are factory-made building blocks. They come in a great variety of sizes, either plain or reinforced. They are used for building walls and roofs.

Gypsum plaster board consists usually of a sheet of set gypsum plaster between two sheets of unsized paper. It comes in many sizes, usually about 3 feet square by 3/8 inch thick. It is used instead of lath as a backing for plaster.

Gypsum wall board is of about the same construction as gypsum plaster board, but the paper is sized so as to furnish the finished surface of the wall. It comes in strips of 4 feet wide by any length from 6 to 14 feet, by 5/8 inch thick.

The Bureau is coöperating with the Gypsum Industries Association in research work on this subject, and the Association has established a fellowship at the Bureau.

Recommended specifications for calcined gypsum, neat gypsum plaster, gypsum plaster board, and gypsum wall board are given in full, for which the original paper should be consulted.

EFFECT OF THE RATE OF COOLING ON THE MAGNETIC AND OTHER PROPERTIES OF AN ANNEALED EUTECTOID CARBON STEEL.[4]

By C. Nusbaum and W. L. Cheney.

[ABSTRACT.]

Six specimens of eutectoid carbon steel were selected, heated to 800° C., and allowed to cool at various rates. One was cooled in air, another in lime, and the others in the furnace at slower and slower rates. Observations were then made to determine the magnetic and other properties. Normal induction measurements at ordinary magnetizing forces were made with the Burrows permeameter and at high field values with a modified form of "isthmus method." Resistance measurements were made by a comparison method; the "fall of potential," both across the terminals of a standard shunt connected in series with the current-carrying specimen and across knife-edge terminals in contact with the specimen, was measured by a Wolff potentiometer. Hardness measurements were made by means of a self-recording Shore scleroscope. Micrographs were made at a magnification of 500 diameters, representing the average structural condition shown by etching for 10 seconds in 5 per cent. alcoholic picric acid. There is found a marked difference in structure among the furnace-cooled, the air-cooled, and the lime-cooled specimens.

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[4] Scientific Paper No. 408.

A table is given showing the time each specimen was held at 800° C., the nature of the cooling, the time of cooling from 800° C. to 650° C., the maximum permeability, the induction for particular values of the magnetizing force, the residual induction, the coercive force, the maximum intensity of magnetization, the hardness, and the resistivity. Figures are also included which show the normal induction, the permeability, and the reciprocal of the susceptibility plotted against the magnetizing force, as well as the time-temperature curves.

The experimental results show:

1. With a decrease in the cooling rate there is a marked increase in the value of the maximum induction for a given value of the magnetizing force, an increase in the maximum permeability, and a decrease in the coercive force.

2. As the structure is changed from an essentially sorbitic one to "divorced" pearlite, there is a gradual shifting toward the origin of the break in the reductivity line and an increase in the difference between the "real" and "apparent" values of the maximum intensity of magnetization.

3. There is a good agreement between the values of the coercive force and the scleroscope hardness as influenced by the various cooling rates.

A SIMPLE PORTABLE INSTRUMENT FOR THE ABSOLUTE MEASUREMENT OF REFLECTION AND TRANSMISSION FACTORS.[5]

By A. H. Taylor.

[ABSTRACT.]

A NEW type of absolute reflectometer was recently described in Scientific Paper No. 391 of the Bureau of Standards. The operation of that instrument is somewhat complicated, and a much simpler one has now been devised. This new instrument, like the one previously described, is based on the principle of the integrating sphere, but is operated in an entirely different manner.

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[5] Scientific Paper No. 405.

The reflectometer is a sphere with a small segment cut away, leaving a hole over which the surface to be tested is placed. The wall of the sphere is viewed through a small hole by means of a portable photometer, the spot viewed being screened from the test surface. A lighting tube, set at an angle to the sphere surface, is arranged to rotate about an axis normal to the surface of the sphere, so that the direct light can be thrown on the test surface or on the sphere wall. The theory of the integrating sphere shows that the reflection factor of the test surface is simply the ratio of the photometer readings in the two cases, no assumption being made as to the way in which the light is reflected from the test surface. Moreover, the reflection factor measured is not affected by selective reflection by the sphere walls.

No accurate voltage adjustment of the lamps in the photometer and the reflectometer is necessary, as both operate from the same battery. The use of a low-voltage flashlight lamp in the lighting tube makes the instrument very portable and convenient. An absolute instrument of this type is much better than an instrument giving relative values because no standard surface is required and it is not necessary for lamps or sphere surface to remain constant from day to day. By the addition of an exterior light source the same instrument can be used to measure transmission factors of clear or diffusing media.

NATIONAL SAFETY CODE FOR THE PROTECTION OF THE HEADS AND EYES OF INDUSTRIAL WORKERS.[6]

[ABSTRACT.]

IN 1918 the Bureau of Standards coöperated with the safety engineers of the War and Navy Departments in the preparation of a set of safety standards to be applied in the government establishments. Among these standards was one for head and eye protection, and this formed the basis for the National Safety Code for the Protection of the Heads and Eyes of Industrial Workers. These rules were further developed through study and experimental work at the Bureau, and conferences with other individuals who have had experience in eye protection.

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[6] Handbook of the Bureau No. 2.

Preliminary drafts were issued in December, 1918, and in May, September and December, 1919, and in March and August, 1920, further revisions were made. In this work the Bureau wishes to acknowledge the assistance rendered by the Advisory Committee. The rules are designed to give mechanical and optical protection to the eyes and heads of workers in certain occupations which involve such hazards.

No attempt has been made to specify a particular style and strength of goggle for a particular operation, but rather an attempt has been made to classify the character of the hazards which are existent in industry, leaving it to the employer, or the administrative authority or other responsible party, to assign the particular operation concerned to its proper group.

The various operations and processes which require protection to the head and eyes have been classified into nine groups according to the degree of hazard, or because the peculiar nature of the hazard makes it necessary to provide a protector having distinctive features.

The hazards from flying solid particles ordinarily encountered are separated into three groups designated A, B, and C. The first group will contain all operations wherein the mechanical hazard is so great as to warrant the selection of protectors the parts of which have passed mechanical tests assuring adequate strength. In class B are grouped all operations in which the protector must prevent the entrance of small flying particles into the eye. The lens will not be subjected to severe blows and hence no mechanical tests are necessary. While strength of the frames of goggles used for this purpose is not a prime requisite, definite requirements for the material entering into their construction is necessary. Hence a separate group for these processes has been made. In class C, occupations similar to auto driving, protectors are used merely to keep small foreign particles out of the eyes, and hence the protector need not withstand any special strength tests.

In processes where splashing metal is used the special hazard is from burns from molten metal which might be projected with force. The degree of hazard varies with the operations, and therefore a number of different methods of protection are suitable. Workers handling fumes, gases, and liquids require protectors of various designs, each one having protective qualities peculiarly fitted for the work. These operations have accordingly also been classed in a separate group.

The hazards incident to sand-blasting are not met in any other process. Hence this subject is treated separately.

In the last three groups are classified all of the operations where the worker is exposed to harmful radiant energy. Definite limits to the transmission of the radiant energy through the lens or window of the protector have been set. These limits are based on the degree of hazard involved, an analysis of which results in the division of hazards into three groups. The Bureau will be glad to receive criticisms of the provisions and recommendations for improvement of the Code, especially such as are based upon actual experience in the application of the rules. After a period of trial and experience it is expected to issue a new edition with such changes and corrections as that experience may dictate.

The rules are accompanied by a discussion intended to assist in their interpretation and application and to show the reasons for including some of them in the text.

REPORT OF THE THIRTEENTH ANNUAL CONFERENCE ON WEIGHTS AND MEASUURES.[7]

[ABSTRACT.]

The Annual Conference on Weights and Measures of the United States is an organization composed of State and local weights and measures officials from all parts of the country, which meets yearly at the Bureau of Standards, Washington, D. C. These Conferences are also largely attended by representatives of manufacturers of weighing and measuring devices and by other guests interested in the general subject of weights and measures. The Conference is vitally concerned with the improvement and efficient enforcement of Federal, State, and local weights and measures laws and with the improvement of rules and regulations, specifications and tolerances, and methods of inspection. It also considers means to bring about a greater measure of uniformity throughout the country in these matters.

This publication is a verbatim report of the proceedings of the thirteenth annual meeting. It contains addresses by the Secretary of Commerce and by the president of the Conference; reports of delegates representing various States as to conditions in their jurisdictions; papers on the subjects of gasoline pumps from the standpoint of safety, net weight, the weight standardization of bread, the standardization of containers for foodstuffs, weights and measures education in the schools, and machine measurements for dry-goods; and the resolutions adopted by the Conference. The report of the committee on specifications and tolerances which was devoted to the subject of liquid-measuring devices is given, as well as the discussion concerning the various provisions. The appendix consists of the complete specifications and tolerances adopted for this class of apparatus.

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[7] Miscellaneous Publication No. 43.

EFFECT OF REPEATED REVERSALS OF STRESSES ON DOUBLE REINFORCED CONCRETE BEAMS.[8]

By W. A. Slater, G. A. Smith and H. P. Mueller.

[ABSTRACT.]

THE tests reported in this paper were made as a part of the investigations carried out in the concrete-ship program of the Emergency Fleet Corporation. The purpose was to stimulate to some extent the effect produced upon a ship by the action of the waves which causes an alternate upward and downward deflection of the ship. This is the action known in ship-building terms as " hogging " and " sagging."

The specimens used for the test were concrete beams which had reinforcement both in the top and in the bottom. The beams were 4 by 6 inches in cross section over all and were tested with a span of 8 feet. The load was applied at points 12 inches apart, each point being 6 inches from the centre of the span. It was applied at the rate of about seventeen cycles per minute (one cycle includes one application of load upward and one application of load downward). The load was applied as dead weight by means of levers so designed that ten times as much load came upon the beam as was applied to the lever. The levers were operated by means of an electric motor acting through a walking beam.

Four beams were tested to failure and a fifth was loaded alternately through two million cycles when the test was discontinued. At the time of discontinuation of the test the beam did not appear to be approaching failure.

For all of the beams tested to failure, failure was by tension in the steel. Generally the beams in which the highest stresses were developed in the test withstood a smaller number of repetitions of load than those in which the measured stresses were smaller. However, even the largest number of repetitions was so small that failure in the steel would not have been expected at the time at which it did occur considering that the observed stresses were very low. Other factors than the intensity of the tensile and compressive stresses seem to have had a part in bringing about the early tension failure.

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[8] Technologic Paper No. 182.

All of the tension failures in the reinforcing bars occurred at sections where large cracks extended entirely across the section of the beam. It is possible that in some cases the bending at these cracks was sufficient to make the bending of the bar an important factor in causing failure. The slipping of bars at the ends, such as happened in one of the beams, would permit the opening of wide cracks and accentuate this tendency.

The presence of the gage holes in the bars seems to have had some influence in hastening tension failure, but this influence was not very distinct.

The quality of steel used for most of the reinforcement was poor and this would contribute to bringing about early failure. However, this alone would not account for the small number of repetitions of stress generally required in these tests to produce failure.

After 7000 cycles of load the slip at the end of the bar in one of the beams was less than 0.001 in.; that is to say, less than the amount which has been taken as the criterion of safe conditions based on tests of the bond resistance between concrete and steel. Yet, after 400,000 cycles of load, the amount of slip had increased so much that failure by slipping of the bars seemed imminent. It seems that the intervention of tension failure at an unexpectedly small number of repetitions of load prevented the bond failure of this specimen.

PHYSICAL PROPERTIES OF MATERIALS: COMPILED TABLES. I. STRENGTHS AND RELATED PROPERTIES OF METALS AND CERTAIN OTHER ENGINEERING MATERIALS.[9]

[ABSTRACT.]

THIS circular aims to present, in readily accessible form, the best available data on the strengths and related properties of metals, alloys, and certain non-ferrous metals. Among the materials treated are iron, carbon steels, alloy steels; wire and wire rope; semi-steel; aluminum, copper, and miscellaneous metals and their alloys; rope, rubber, leather, and woods.

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[9] Circular No. 101.

The tensile strength, proportional limit, percentage elongation in two inches, percentage reduction of area, Brinell and scleroscope hardness corresponding to a certain composition, density and method of preparation are shown in most cases for the metals and alloys.

In addition, figures are shown in many instances for the compressive and shearing strengths, modulus of rupture and Erichsen value.

The circular also includes definitions of the properties treated and references to sources.

EXPERIMENTS ON COPPER CRUSHER CYLINDERS.[10]

By Alexander I. Krynitsky.

[ABSTRACT.]

THE metallic cylinders, usually made of exceedingly pure copper or lead, employed for the measurement of pressure developed by the products of decomposition of powder in the testing of powder and ammunition, are known as crusher cylinders.

On firing, the pressure of the gases shortens the cylinder longitudinally by means of the piston of the special apparatus used. The amount of this compression, in conjunction with the proper value taken from a previously prepared table of values showing the relation between the compressions and corresponding total sets of the length of each lot of cylinders, serves to determine the maximum pressure of the products of decomposition. These copper cylinders are the subject of this investigation, which was carried out in 1919 by the Bureau of Standards in connection with the standardization of the crusher gage method for pressure testing of small arms, ammunition, and powder, and which consisted of a series of compressions of the annealed copper cylinders, one set having a mean length of 0.4000 in. and the others 0.5000 in., with a mean diameter of 0.2260 in. in the former and 0.2500 in. in the later ones, on a standard 10,000-lb. Riehlé testing machine. From the results of these investigations it appears that:

1. The length of copper crushed cylinders decreases consider-

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[10] Technologic Paper No. 185.

ably under repeated application of the same load. The relation between this decrease in length and number of times load was applied is within certain limits nearly proportional.

2. The change in length with repeated constant loads is greater with the greater load.

3. Repeated application of successive decreasing loads within certain limits causes a gradual decrease in length.

4. The length changes but slightly with longer application of load when the load is applied in such a manner as to produce the maximum stress only for an instant.

5. Application of the same load for the same period (greater than about 3 seconds), but holding the beam balanced by means of one additional application (impulse) of the same load after the beam had started to drop, causes about twice the decrease in length observed in the previous case, when the beam was allowed to drop after balance was obtained.

6. Double applications of the same load for 2½ seconds each time, the second load being applied at some interval after the first load has been released, causes a decrease in length much greater than in the previous two cases. This holds true even when the pressure is applied for as long as 25 seconds in the case of paragraphs 4 and 5.

7. In case the last load is considerably greater than any previous loads, the change in length due to last load is practically independent of the previous loads, *i.e.*, it is the same as would be obtained by compressing a previously uncompressed cylinder.

8. When two successive loads of considerable amount (approximately 40,000 lbs. per sq. in.) are applied, the second being greater than the first, the change in length due to the last load is considerably greater than that obtained where the pressure is applied on previously uncompressed cylinders, and this difference increases as the difference between the two loads successively applied decreases.

9. When several successive loads of considerable amount are applied, differing by about 2000 lbs. per sq. in., each greater than the preceding load, the total change in length of the cylinders following the last compression increases with the number of loads previously applied.

10. It appears probable that aging at temperatures within 0–100° C. softens the compressed copper somewhat.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

REFLECTION CHARACTERISTICS OF PROJECTION SCREENS.[1]

By L. A. Jones and M. F. Fillius.

The importance of using a surface of proper reflection characteristics in the projection of motion pictures is emphasized. A gonio photometer constructed especially for the measurement of the reflection characteristics of surfaces is described and its use explained. The results of measurements on some thirty-six different surfaces consisting largely of commercial motion-picture screens are given. These screens are shown to fall into three general classes, according to the completeness with which the reflected light is diffused. In Class A are included those screens which reflect a large proportion of the incident light within a very narrow angle, while in Class C are those screens which give almost complete diffusion. Class B includes the screens which are intermediate between the extremes represented by classes A and C. A graphic representation of the distribution of reflected light is given for each of the screens examined. On the assumption that the brightness of a screen as viewed on the axis should not be greater than four times the brightness when observed at the maximum angle, a method of choosing a screen for any particular condition was outlined and the constants of the various screens necessary for the making of such a choice are computed and tabulated.

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* Communicated by the Director.

[1] Trans. Soc. Mot. Pict. Eng., No. 11, p. 59. Communication No. 114, from the Research Laboratory of the Eastman Kodak Company.

Heating by Catalysis. (*La Nature,* December 25, 1920.)—Early in the nineteenth century Humphry Davy discovered that a spiral of platinum, previously heated, will remain incandescent when immersed in a mixure of air and inflammable gas. While the platinum remains unchanged the gas is decomposed. From this simple beginning have grown the many catalytic processes now known. The manufacture of sulphuric acid by the contact process is an example of the practical application of catalysis.

In the winter of 1914–1915 the French aviation service experienced vexation from the delay in starting the motors, due to the too low temperature of the water or of the radiators. Loss of time in setting out brought in its train failure to attain the purpose of the flight. This difficulty was overcome by Messrs. L. Lumière and J. Herck, who devised a catalytic heater that kept the radiator warm and at the same time avoided any danger of setting on fire the very inflammable avion.

In the bottom of a metal cylinder is a spongy body, such as sheet cotton, soaked with gasoline. From this a wick extends upward and terminates a short distance below a plug of asbestos impregnated with platinum. At the beginning this platinized plug is heated, then as the gasoline vapor continues to come in contact with it, chemical change by catalysis is brought about so that a temperature of about 250° C. is maintained without a flame. A company is now making heating apparatus of this kind, designated as "Thermix," ranging in size from such as will heat the pocket or a muff to those designed to temper the coolness of a room. For 60 cu. m. an hourly consumption of 120 grams of gasoline is the rating.

G. F. S.

Crisis in the American Potash Industry. (*A. C. S. News Service,* C-250-2, 1-25-21.)—Dr. John E. Teeple recently presented before the Rochester section of the A. C. S. some statements as to the falling off in the manufacture of potash fertilizers in this country.

In 1918, the banner year, 128 different plants operated, giving a total production of over 54,000 tons of potassium oxide. In 1919, with the fall of the price of potash, this production dropped to about 30,000 tons. Out of the 128 plants reported as producing in 1918, only 43 were reported as producing in 1920. With the price of potash in 1921 still lower than it was in 1920, we may expect a still greater falling off in the number of producing plants, and possibly in the total output.

Up to the present time probably 70 per cent. of the total production of potash in this country came from the natural brines found in certain lakes in Nebraska, Utah, and California. The largest producer in the United States is a plant working on Searles Lake in California.

NOTES FROM THE U. S. BUREAU OF MINES.*

QUALITY OF GASOLINE MARKETED IN THE UNITED STATES.

By H. H. Hill and E. W. Dean.

In the spring of 1919 a comprehensive survey of motor gasolines sold in the United States was made by the Bureau of Mines. The data obtained in this survey were used by the Committee on Standardization of Petroleum Specifications for setting a new specification for Federal purchases of motor gasoline. The complete report of this investigation with detailed tables of analyses has recently been issued as Bulletin 191 of the bureau.

INVESTIGATION OF COLORADO LOW-GRADE ORES.

By R. R. Hornor and W. H. Coghill.

The investigation of low-grade and complex ores in Colorado, conducted jointly by the U. S. Bureau of Mines and the Colorado School of Mines under a fund appropriated by the State legislature, has been completed. The object of the investigation was to determine the character and extent of the low-grade ores in the State and, where found in sufficient quantity, to conduct concentration tests in an effort to devise a cheap and suitable treatment. The results are being published as Bulletin 10 of the Colorado Bureau of Mines.

CHLORINATION OF NATURAL GAS.

By G. W. Jones.

The Bureau of Mines has conducted, in its natural-gas laboratories at Pittsburgh, an investigation of the making of useful products by the chlorination of natural gas. Many gas fields yield natural gas which is free from the higher paraffins and is especially suitable for making chlorinated products. In those fields which are too remote from industrial centres to warrant expense of piping, utilization of the gas for the manufacture of chlorinated products seems desirable, if such manufacture can be placed on a feasible and profitable basis. Since "wet" gases are being utilized for obtaining gasoline, whereas "dry" gases are of no value for gasoline production but offer possibilities for chlorination, only the "dry" gases were studied.

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* Communicated by the Director.

The studies were confined to the effect of catalyzers on the chlorinating reaction, also the effect of temperature, and to a smaller extent, that of water vapor. Details of the experiments and the results obtained are given in Technical Paper 255, "Chlorination of Natural Gas," by G. W. Jones, V. C. Allison and M. H. Meighan.

TESTS OF CARBON MONOXIDE DETECTOR IN MINES.

By D. Harrington.

ONE of the products of the U. S. Chemical Warfare Service is a simple, portable instrument for quick determination of small quantities of carbon monoxide in air. The device has been diverted to commercial uses for determination of small but possibly dangerous quantities of CO in garages, sewers, etc. Recent tests by the Bureau of Mines indicate that it probably has a definite field of use in testing mine air in connection with fires and explosions and in confined places, suspected to contain small amounts of CO.

PROPERTIES OF CRUDE OILS FROM EASTERN FIELDS IN UNITED STATES.

By E. W. Dean.

THE Bureau of Mines is making a comprehensive study of the properties of crude oils from the various producing fields in this country. Typical samples are collected and analyzed for specific gravity, sulphur content, water content, distillation products, and carbon residue percentage in residuum from distillations. The chief value of the results of this work is that they permit comparisons of different types of crude oil, which has never before been possible.

A preliminary report covering the crude oils from the eastern fields has been issued by the bureau in mimeographed form.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 16, 1921.)

Hall of The Franklin Institute,
Philadelphia, February 16, 1921.

President Dr. Walton Clark *in the Chair.*

Additions to membership, since last report, 9.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The following gentlemen nominated by the Board of Managers were unanimously elected to honorary membership:

Prof. Charles Fabry, University of Paris, Paris, France.

Frank J. Sprague, Esq., 165 Broadway, New York, N. Y.

The standing committees for the year 1921–1922 were announced.

Mr. Charles W. Masland, Chairman of Committee on Science and the Arts, then introduced Mr. Jacob M. Spitzglass, of Chicago, Illinois, to whom had been awarded the Edward Longstreth Medal of Merit for his meter for measuring the flow of fluids. The President presented the medal and accompanying documents to Mr. Spitzglass, who thanked the Institute for the honor conferred upon him.

The paper of the evening, entitled " The Bearing of a Synthetic Dye Industry Upon Our National Welfare," was presented by Col. Marston Taylor Bogert, A.B., Ph.B., LL.D., Professor of Organic Chemistry, Columbia University, New York City. A brief outline was given of the synthetic dye industry, followed by a detailed description of the utilization of the by-products and intermediates for the production of important medicinals, explosives, incendiaries, war gases, photo-chemicals, inks, perfumes, artificial resins, etc. The impetus and encouragement which the dye industry has given to chemical research and the effect of the same upon the teaching of chemistry in our educational institutions, was considered briefly. The subject was illustrated by samples of many of the compounds manufactured and by the actual preparation upon the lecture table of a number of them.

A brief discussion followed the reading of the paper, in which Mr. Masland, Dr. Keller and Mr. Tutwiler participated.

On motion, duly seconded, the thanks of the meeting were extended to the speaker. Adjourned.

R. B. Owens,
Secretary.

STANDING COMMITTEES, 1921,

OF THE BOARD.

ELECTIONS AND RESIGNATIONS.

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Alfred W. Gibbs
Howard S. Graham
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Wm. Chattin Wetherill

MEETINGS.

Gellert Alleman
Charles Baskerville
G. H. Clamer
A. S. Cushman
George R. Henderson

MEETINGS *(Continued)*.

Joseph S. Hepburn
H. E. Ives
A. E. Kennelly
M. M. Price
George D. Rosengarten

MUSEUM.

Hugo Bilgram
Arthur L. Church
Henry F. Colvin
Charles Day
George A. Hoadley
C. W. Masland
A. E. Outerbridge, Jr.
H. H. Quimby
Charles Penrose
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 2, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1921.

MR. CHARLES PENROSE *in the Chair.*

Mr. Charles W. Masland was unanimously elected Chairman for the year 1921.

The following report was presented for First Reading:

No. 2761: Greaves-Etchells Electric Arc Furnace. This case was referred back to the Sub-Committee.

The following reports were presented for Final Action:

No. 2750: Tate Waterproofing Process,

No. 2770
No. 2771
and
No. 2772
Literature, Consideration of articles published in the JOURNAL for the year 1920.

R. B. OWENS,
Secreatry.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 27, 1921, at 8 o'clock, Dr. Harry F. Keller in the Chair. The minutes of the previous meeting were read and approved.

Mr. James O. Lewis, of Marietta, Ohio, Petroleum Engineer, Consulting Engineer to the U. S. Bureau of Mines, and formerly in charge of the petroleum work of the Bureau of Mines, presented a communication on "America's Petroleum Problem." An outline was given of the American petroleum industry. The sources of domestic supply and the total crude oil supply of the world were discussed. The lecture concluded with an account of the various ways in which the domestic supply may be so increased as to meet the growing demand. Lantern slides were used to illustrate the lecture.

The communication was discussed at length; a vote of thanks was extended to Mr. Lewis; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 3, 1921, with Dr. George A. Hoadley in the Chair.

Louis Cohen, Ph.D., Consulting Engineer, Washington, D. C., and Major J. O. Mauborgne, Office of the Chief Signal Officer, Washington, D. C., presented a communication entitled, "A New Method for the Reception of Radio Signals, Eliminating Static and Interference." The general problem of radio-receiving circuits from the standpoint of selectivity was considered and a résumé was presented of previous efforts in the design of radio-receiving circuits to secure freedom from interferences. A description was given of a new type of circuits for receiving radio signals, recently developed by the speakers, making use of resonance wave coils, which effects a great reduction in interferences, either that of nearby stations or of static disturbances. The subject was illustrated by lantern slides.

After a brief discussion the thanks of the meeting were extended to the speakers.

Adjourned.

R. B. OWENS,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 10, 1921, at 8 o'clock. The meeting was called to order by Mr. Coleman Sellers, Jr.

Mr. Frank S. Clark, Mechanical Engineer, Stone and Webster, Inc., Boston, Mass., presented a communication entitled, "Modern Steam Power Station Design." A brief outline was given of the development of the art of power-station design corresponding with the progress in the design and construction of station equipment, and the points to be observed in order to secure reliability of service by proper selection, arrangement and installation of equipment were discussed. Consideration was also given to the various factors affecting the choice of design and sizes of units, such as character of service, peak load, load factor (annual and daily), growth of load, probable ultimate capacity and local topographical and other conditions peculiar to the available sites. The economy of station operation and its attainment by the working out of the proper heat balance, the selection of the operating steam pressure and temperature, the fuel to be used and the simplicity and compactness of the arrangement were discussed in detail. The paper was illustrated by lantern slides.

After a discussion the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 9, 1921.)

RESIDENT.

MR. BEAUVEAU BORIE, JR., 135 South 18th Street, Philadelphia, Pennsylvania.
DR. HENRY M. CHANCE, 839 Drexel Building, Philadelphia, Pennsylvania.
DR. C. E. FERREE, Bryn Mawr College, Bryn Mawr, Pennsylvania.
MR. GEORGE E. KINNIER, 20 Red Bank Avenue, Woodbury, New Jersey.

NON-RESIDENT.

DR. LOUIS W. AUSTIN, Naval Research Laboratory, Bureau of Standards, Washington, D. C.

MR. WM. ARTHUR COWAN, 129 York Street, Brooklyn, New York.

MR. FREDERICK S. DELLENBAUGH, JR., 91 Spooner Road, Chestnut Hill, Massachusetts.

DR. EUGENE L. MAINES, Ellis Hotel, Chattanooga, Tennessee.

ASSOCIATE.

MR. ARTHUR W. BINNS, 1929 Poplar Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. JOHN C. BULLITT, 3RD, 1811 Walnut Street, Philadelphia, Pennsylvania.

MR. ALBERT LADD COLBY, 447 Brighton Street, Bethlehem, Pennsylvania.

PROF. CHARLES FABRY, University of Paris, 1, rue Victor-Cousin, Paris (5*e*), France.

MR. C. E. FOSTER, 1826 Spruce Street, Philadelphia, Pennsylvania.

DR. ENOCH KARRER, Nela Research Laboratory, Nela Park, Cleveland, Ohio.

MR. E. E. KELLER, 717 Mt. Hope Avenue, Rochester, New York.

MR. HAROLD T. MAITLAND, Sharon Hill, Pennsylvania.

MR. H. CONRAD MEYER, 203 East Willow Grove Avenue, Chestnut Hill, Pennsylvania.

DR. WM. H. NICHOLS, The Allied Chemical and Dye Corporation, 61 Broadway, New York City, New York.

MR. CARL D. ULMER, Minnesota By-Product Coke Company, 1000 Hamline Avenue, St. Paul, Minnesota.

NECROLOGY.

Mr. Frank Firmstone, Easton, Pennsylvania.

Thomas D. Mowlds, Esq., 1001 Chestnut Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

CAYLEY, A.—Collected Mathematical Papers. Vols. 2 to 13.

DALBY, W. E.—Steam Power. 1920.

DENNIS, L. M.—Gas Analysis. 1920.

EINSTEIN, A.—Relativity. 1920.

FALK, K. G.—Chemical Reactions. 1920.

GRABAU, A. W.—Geology of the Non-Metallic Mineral Deposits. 1920.

LOVETT, W. J.—Applied Naval Architecture. 1920.

MCKAY, G. L., AND C. LARSEN.—Principles and Practice of Butter Making. No date.

POYNTING, J. H.—Collected Scientific Papers. 1889.

STOCKING, W. A.—Manual of Milk Products. 1919.

VAN SLYKE, L. L.—Modern Methods of Testing Milk. 1920.

GIFTS.

Allied Machinery Company, Catalogue Describing Drilling Machines. New York City, New York, 1920. (From the Company.)

Alpha Electric Company, Incorporated, Catalogue No. 20. New York City, New York, 1920. (From the Company.)

Alpha Portland Cement Company, Alpha Aids. Easton, Pennsylvania, 1920. (From the Company.)

Anderson Brothers Manufacturing Company, Anderson Pneumatic Scraper. Rockford, Illinois, 1920. (From the Company.)

Anderson Electric and Equipment Company, Catalogue No. 3. Chicago, Illinois, 1920. (From the Company.)

Armstrong Machine Works, Catalogue C. Three Rivers, Michigan, 1920. (From the Works.)

Automatic Fuel Saving Company, Fuel Saving Device and Gray System Results. Boston, Massachusetts, 1920. (From the Company.)

Ball Engine Company, Bulletins Nos. S–16, S–22, S–30, S–36. Erie Pennsylvania, 1920. (From the Company.)

Bartlett and Snow Company, Bulletin No. 45. Cleveland, Ohio, 1920. (From the Company.)

Boiler Kote Company, The Boiler Kote Method. Chicago, Illinois, 1920. (From the Company.)

Bristol Company, Bulletins Nos. 303–291. Waterbury, Connecticut, 1920. (From the Company.)

Brown Portable Conveying Machinery Company, Bulletin No. 30. Chicago, Illinois, 1920. (From the Company.)

Brown and Shape Manufacturing Company, Catalogue No. 137. Providence, Rhode Island, 1920. (From the Company.)

Brown-Wales Company, Catalogue on Structural Material, Sheets and Plates. Boston, Massachusetts, 1920. (From the Company.)

Buffalo Forge Company, Fan System of Heating, Ventilating and Humidifying, and Standard Pipe Coil Heaters. Buffalo, New York, 1920. (From the Company.)

Canton Foundry and Machine Company, Canton Alligator Shears, Portable Floor Crane and Hoist. Canton, Ohio, 1920. (From the Company.)

Case School of Applied Science, Catalogue for 1920–1921. Cleveland, Ohio, 1920. (From the School.)

Cincinnati Planer Company, Treatise on Planers. Cincinnati, Ohio, 1920. (From the Company.)

Chicago Belting Company, Leather Packings and Specialties. Chicago, Illinois, 1920. (From the Company.)

Chicago Pneumatic Tool Company, Bulletin No. 389. Chicago, Illinois, 1920. (From the Company.)

Chrobaltic Tool Company, Chrobaltic High Speed Cutters. Chicago, Illinois, 1920. (From the Company.)

Columbia Hardware Company, Catalogue No. 1901–A. Cleveland, Ohio, 1920. (From the Company.)

Cooper Hewitt Electric Company, Studies in the Economics of Lighting. Hoboken, New Jersey, 1920. (From the Company.)

Cooper Union, Sixth Annual Report for 1919. New York City, New York, 1920. (From the Cooper Union.)

Crouse Hinds Company, Bulletin No. 1000 R. Syracuse, New York, 1920. (From the Company.)

Cutler-Hammer Manufacturing Company, Motor Control Apparatus. Milwaukee, Wisconsin, 1920. (From the Company.)

De Laval Steam Turbine Company, Bulletin S, Centrifugal Pumps for Sugar House Service. Trenton, New Jersey, 1920. (From the Company.)

Electric Furnace Company, Booklet 9–B. Salem, Ohio, 1920. (From the Company.)

Engineer Company, Modern Practice in Combustion Control. New York City, New York, 1920. (From the Company.)

Engineers School; Sound Ranging and Military Mining. Washington, District of Columbia, 1920. (From the School.)

Eureka Battery Company, Catalogue No. 10. Chicago, Illinois, 1920. (From the Company.)

Foster Marine Boiler Corporation, Catalogue No. 51. New York City, New York, 1920. (From the Corporation.)

General Electric Company, Life in a Large Manufacturing Plant. Schenectady, New York, 1920. (From the Company.)

General Radio Company, Bulletins of Electrical and Radio Laboratory Apparatus. Cambridge, Massachusetts, 1920. (From the Company.)

Graver Corporation, Reap as the Harvester. East Chicago, Illinois, 1920. (From the Corporation.)

Greenfield Tap and Die Corporation, Catalogues Nos, 40, 41, 42, 43. Greenfield, Massachusetts, 1920. (From the Corporation.)

Griscom-Russell Company, Leaflet No. 6, and Bulletins Nos. 225, 240, 231, 230, 228, 311, 1010, 902, 250, 1140, 1110, 1106, 1120. Philadelphia, Pennsylvania, 1920. (From the Company.)

Haiss Manufacturing Company, Incorporated, Booklet No. 820. New York City, New York, 1920. (From the Company.)

Hoadley, George A., Monograph on Illumination. Philadelphia, Pennsylvania, 1920. (From Dr. Geo. A. Hoadley.)

Lamson Company, Lamson Pneumatic Tubes for Conveying Papers and Merchandise. Boston, Massachusetts, 1920. (From the Company.)

Leeds and Northrup Company, A Method of Recording Blast Furnace Temperatures, 1920. (From the Company.)

Link-Belt Company, Booklet on Traveling Water Screens, Books Nos. 375 and 380. Chicago, Illinois, 1920. (From the Company.)

Little, Authur D., Incorporated, The Petroleum Outlook. Cambridge, Massachusetts, 1920. (From the Corporation.)

Living-Stone Company, Catalogue of Products of Living Stone and Litholex. Baltimore, Maryland, 1920. (From the Company.)

Locomotive Superheater Company, Bulletin No. T.–5. New York City, New York, 1920. (From the Company.)

Massachusetts Board of Water Commissioners, Annual Report for the Year Ending March 31, 1919. Cambridge, Massachusetts, 1920. (From the Commissioners.)

Mavor and Coulson, Industrial Switch-Gear. Mile End, Glasgow, 1920. (From Mavor and Coulson.)

Moore Shipbuilding Company, Booklet. Oakland, California, 1920. (From the Company.)

National Carbon Company, Incorporated, The Carbon Electrode. New York City, New York, 1920. (From the Company.)

National Tool Company, Catalogue E. Cleveland, Ohio, 1920. (From the Company.)

Nebraska State Railway Commission, Twelfth Annual Report for 1919. Nebraska, 1920. (From the Commission.)

New Jersey Department of Conservation and Development, Bulletin No. 20. Trenton, New Jersey, 1920. (From the Department.)

Newton Machine Tool Works, Inc., Bulletin Nos. 54–55. Philadelphia, Pennsylvania, 1920. (From the Works.)

New York Public Service Commission, Second District, Thirteenth Annual Report for the Year 1919. Albany, New York, 1920. (From the Public Service Commission.)

Ohio Brass Company, Electric Arc-Welding. Mansfield, Ohio, 1920. (From the Company.)

Ontario Department of Mines, Twenty-ninth Annual Report, Part vi. Toronto, Canada, 1920. (From the Department.)

Pennsylvania Forge Company, Catalogue No. 3. Bridesburg, Pennsylvania, 1920. (From the Company.)

Philadelphia Department of City Transit, Annual Reports for the Years of 1917, 1918 and 1919. Philadelphia, Pennsylvania, 1920. (From the Department.)

Philadelphia Municipal Court, Report 1919; Chilton Automobile Directory, January, 1918, and 1919. (From Mr. Chas. A. Duryea.)

Philip Carey Company, Catalogue No. 1362. Lockland, Cincinnati, Ohio, 1920. (From the Company.)

Princeton University Observatory, Contributions No. 5, The Eclipsing Variable U Cephei. Princeton, New Jersey, 1920. (From the University.)

Pyrolectric Instrument Company, Pyrolectric Bi-monthly Bulletin No. 14, 1920. Trenton, New Jersey. (From the Company.)

Reading Iron Company, Bulletin No. 1. Reading, Pennsylvania, 1920. (From the Company.)

Robinson Connector Company, Booklet on the Robinson Connector. New York City, New York, 1920. (From the Company,)

Scott Valve Manufacturing Company, Catalogue No. 12. Detroit, Michigan, 1920. (From the Company.)

Shope Brick Company, Shope Concrete Brick. Portland, Oregon, 1920. (From the Company.)

Smith Gas Engineering Company, Bulletins Nos. 12, 12A, 16, 11. Dayton, Ohio, 1920. (From the Company.)

Sprague Electric Works, Bulletin No. 48,961. New York City, New York, 1920. (From the Works.)

Tyler, W. S., Company, Catalogues Nos. 42 and 50. Cleveland, Ohio, 1920. (From the Company.)

United States Council of National Defense, Fourth Annual Report for the Year Ending June 30, 1920. Washington, District of Columbia, 1920. (From the Council.)

United States Radiator Corporation, The Complete Line. Detroit, Michigan, 1920. (From the Corporation.)

Van Dorn Electric Tool Company, Bulletin on Improved Heavy Duty Ball-Bearing Electric Grinders and Buffers. Cleveland, Ohio, 1920. (From the Company.)

Vassar College, Fifty-sixth Annual Catalogue, 1920–1921. Poughkeepsie, New York, 1920. (From the College.)

Walworth Manufacturing Company, Catalogue No. 78. Philadelphia, Pennsylvania, 1920. (From the Company.)

Whiting Foundry Equipment Company, Foundries and Their Complete Equipment. Harvey, Illinois, 1920. (From the Company.)

Wilmington Board of Water Commissioners, Forty-ninth and Fiftieth Annual Reports, 1917, 1918–1919. Wilmington, Delaware, 1920. (From the Commissioners.)

Wood, Wm. H., Loco Fire Box and Tube Plate Company, Economics in Railroad Problems. Media, Pennsylvania, 1920. (From Mr. William H. Wood.)

BOOK NOTICES.

INTRODUCTION TO GENERAL CHEMISTRY. An Exposition of the Principles of Modern Chemistry, by H. Coupaux, Professor of Mineral Chemistry at the School of Industrial Physics and Chemistry of the City of Paris. Translated by Henry Leffmann, A.M., M.D. 195 pages, with 30 illustrations. P. Blakiston's Son and Co., Philadelphia, 1920. $2.00.

In the author's preface it is stated that Van't Hoff once asserted that he had not understood Avogadro's postulate until it became his duty to teach it. It may be possible that the owners of less brilliant minds than that of Van't Hoff would confess having made the same observation in their own experiences, particularly in these times, when the simplest equation of former days is accompanied by a mathematical formula or two.

The physicists are taking all the joy out of life for the chemists, and as a rule are several squares above them in the graph of mathematical accomplishment, but in this case honors are even, for it doesn't seem to be possible to increase the viscosity of an elementary work to any higher degree without clogging the mental processes of the student.

The chapter headings are indicative of the scope of the work, and are as follows:

1. The Idea of the Element. The Law of Conservation of Matter.
2. Laws of Chemical Combination.
3. Atomic Theory. Chemical Formulas.
4. General Characters and Interrelations of the Elements.
5. Properties and Theory of Solutions.
6. Chemical Affinity.
7. Thermo-Chemistry.

The subject, it will be seen, is developed gradually and logically along orthodox lines of arrangement. Each principle, axiom or law, is well illustrated by examples, and exceptions are noted where these are of importance.

One of the most valuable chapters is that on the General Characters and Interrelations of the Elements, for here are discussed some of the most modern conceptions of chemistry as regards valence, electrochemistry, spectroscopy, radioactivity, isotopy and atomic structure.

The other chapters are equally interesting and valuable, but none contains so much that is essentially new.

The chapter on Solutions is particularly well handled, especially in the matter of illustrations, which are numerous and well chosen for their clarifying effect.

The language is smooth and free from idioms, and the translator is to be congratulated upon having made such an important book available to English-speaking chemists.

The book will be a welcome addition to the library of every teacher of chemistry, and will aid advanced students in a material degree to comprehend chemical theory and acquire proper conception of the intimate relation between chemistry and physics.

C. H. LaWall.

Penrose's Annual. The process Year Book. Quarto, 84 pages, many illustrations, plain and colored. Tennant and Ward, New York City. $5.00 net, postpaid.

This is the issue of the 23rd year of this well-known compilation and record of progress in the higher departments of printing. In addition to a large number of full-page illustrations, most of which are in color, interesting and valuable essays are given, among which are to be noted a suggestion for a new method of color photography, an improved method of measuring color, and a new method of sensitizing with dichromate. The latter topic is of special interest in photographic chemistry, and some of the points of the paper may be given here. Originally written in Italian by Professor Namias, it is translated by R. Born. The rules of chemical nomenclature are not followed, but this is usual in the contributions of photographers. Namias starts by pointing out that paper prepared with neutral chromates has a low sensitiveness, and that addition of alkali-carbonates reduces this, and caustic alkalies reduces it still more. In fact, by adding large amounts of these substances the sensitiveness can be destroyed. On the other hand, the keeping qualities are improved by such additions, so that while a paper sensitized with dichromate will keep a day or so only, one containing the neutral chromate will keep for several days. The plan suggested is to prepare the paper with the neutral chromate with addition of alkali-carbonate, and then, when it is to be used, fume it with acetic acid. This fuming is done in a manner similar to that used in fuming silver paper with ammonia. The acid produces a certain amount of dichromate, and the paper acquires much greater sensitiveness. The author thinks that this process can be applied to the production of commercial paper.

It is impossible to give in a review an idea of the beauty of the book. Its numerous and striking color pictures must be seen to be appreciated. The paper, printing and general make-up are delightful sights in comparison with most of the printed matter of to-day.

HENRY LEFFMANN.

FRENCH-ENGLISH MEDICAL DICTIONARY. By Alfred Gordon, A.M., M.D. 8vo, 161 pages. P. Blakiston's Son and Co., Philadelphia. $3.50 net.

The value of a dictionary will depend on the care with which the words are selected so as to cover all terms within the scope of the book. In addition, bilingual dictionaries must provide some system of indicating pronunciation. No two languages of importance present more difficulties in this respect than English and French. Most of the others are fairly phonetic, and the spelling gives some clue to the pronunciation. It is true that the Italian has an awkward trick of changing the spelling for the sake of euphony, but the dominance of euphony is not as absolute as in French. It is hard to say which of the two, English or French, is the worse in its orthoepy. English has the advantage of a much simpler grammar. It has got rid of the absurd system of attaching genders to inanimate objects, and its verb-forms have been reduced to almost the lowest terms of simplicity. Neither of these modifications has taken from the language any power of expression or caused any sacrifice of clearness.

Doctor Gordon has provided an elaborate system of indicating pronunciation, the efficiency of which can only be determined by trial with beginners. It is to be regretted that scholars have not as yet agreed upon an international series of symbols for indicating all sounds in the important languages. Such systems have been suggested but not generally adopted. The statement that French words of more than one syllable are accented on the last syllable may lead to misunderstanding, for the last *written* syllable in many verb-forms is silent.

One fault common to bilingual dictionaries is the inclusion of many words that do not need definition, being so similar in form in both languages. The present work is not free from this stuffing. Opening at random at page 73, one finds a score at least of words of this class. It is true that in such works the difficulty is to determine what not to put in. The book will be of service to those who wish to read French medical contributions in the original.

HENRY LEFFMANN.

THE MICROANALYSIS OF POWDERED DRUGS. By Albert Schneider, M.D., Ph.D., Professor of Pharmacognosy in the College of Pharmacy and of Pharmacology in the College of Medicine, University of Nebraska. Second edition, 8vo, 543 pages, contents, index and 237 illustrations. Philadelphia, P. Blakiston's Son and Co. $5.00 net.

This excellently printed volume contains illustrations of the tissues of all important crude drugs, mostly, of course, from the vegetable kingdom. They have all been drawn free-hand and are, therefore, often somewhat more distinct and characteristic than will be found in practical examinations; at least that is the experience of the present reviewer in his own use of such manuals. The author deserves credit for his care and patience in making the drawings, and every page of the book shows extensive familiarity with the subject in hand. It is, however, worth considering whether, in these days of high perfection of photomicrography and photogravure, it will not be better to use such methods for illustrations than that of free-hand drawing from the microscopic field. The procedure would, of course, scrap a good many cuts, but would be in the long run cheaper and more satisfactory.

A reference is made to photographic work in this field (wrongly designated microphotography) by the late Professor Maisch, which it is stated was not a success, but photographic methods and optical appliances have been greatly improved since that time.

Another point is the waste of space in the arrangement of the illustrations and the appropriate legends. Considering the high cost of paper, a more condensed arrangement should be used. In most cases the legend could be placed in small type on the same page with the drawing, but it is always placed on a facing page, so that, for instance, in the description of aloes, two pages are taken up when a single one would not only be sufficient but really make a neater and more serviceable form. No statement appears on the illustrations or descriptions as to the degree of magnification.

In the preliminary text, a good deal of valuable and interesting information is given as to the bearings of the U. S. P. standards, and of the difficulties in establishing standards that will be adapted to the conditions of trade and manufacture, and at the same time protect the consumer from inferior articles. The dangers to drugs from the different types of parasites are set forth fully and clearly. In connection with the description of microscope technic, some account of the early history of the instrument is given. In a general statement as to the bibliography, Doctor Schneider expresses the opinion that the important literature is to be found almost exclusively in German and French. The data of the book indicate that with the later developments in microscopic work, especially the application of polarizing and other optical accessories, and of processes of microanalysis, much valuable addition to the equipment for detecting adulteration and inferiority in drugs will be obtained. Meanwhile, this work will be at the service of both student and practical worker.

HENRY LEFFMANN.

TREATISE ON GENERAL AND INDUSTRIAL ORGANIC CHEMISTRY. By Ettore Molinari, Professor of Industrial Chemistry at the Royal Milan Polytechnic. Translated by Thomas H. Pope, B.Sc., A.C.G.I., F.I.C. Part 1, 8vo, 441 pages, contents, index and 254 illustrations. Philadelphia, P. Blakiston's Son and Company. $8.00 net.

Molinari's books have had great success, not only in the country of their publication, but by translation into English, French and Spanish. They contain a very large amount of information on both practical and theoretical questions, and, in addition, discussions of some of the sociologic bearings of the chemical industries. It is a matter of some astonishment that an Italian authority should be able to command so much interest among the chemical industries of nations such as the United States, England and France, in which these industries have been so extensively developed. The world has been for many centuries looking to Italy for art, art objects, music and certain types of literature, but its influence in the field of chemistry has not been so striking. It is true that in physics the discoveries of Volta, Galileo, Melloni and the Florentine academicians are familiar.

The present work is translated from the third Italian edition. The practical part, which is preceded by thirty pages of general and theoretical chemistry, begins with a consideration of the aliphatic hydrocarbons, and follows the usual evolution to the more complex alcoholic and acidic derivatives, with their related forms. The closing pages of the book are devoted to compounds containing sulphur and nitrogen. The last section, under the somewhat striking title of "Derivatives of Carbonic Acid," takes up the technology of uric acid, caffeine and other substances of the purin class.

The general character of the work was presented in the review of the first edition and need not be repeated here, as the arrangement and contents of the text are essentially the same. The reviewer had occasion to express his opinion that much of the matter on the principles of chemistry is out of place in such a work, and in these days, when book-making is so expensive, authors should bear in mind that "Brevity is the soul of wit." In connection with the technology of ethyl alcohol, a large amount of information is given on the use of alcohol as fuel, and on its production from other than cereals and fruits. A good deal of space is, however, practically wasted in a discussion of the sociologic and physiologic relations of alcoholic beverages. The statistical data are often interesting, but the statements of cost must be of no practical value, on account of many interfering circumstances. Thus, the statement that chloral hydrate costs 6s per kilo can only apply to a particular time and place.

The translation appears to be well done and the proofreading careful. The chemical nomenclature and the spelling of chemical terms are, of course, British, but we may be thankful that the translator has preserved the metric measures in the statement of quantities.

HENRY LEFFMANN.

PHARMACEUTICAL BOTANY. A text-book for students of pharmacy and science, by Heber W. Youngken, A.M., M.S., Ph.M., Ph.D. Professor of Botany and Pharmacognosy and Director of the Microscopical Laboratories of the Philadelphia College of Pharmacy and Science. Small 8vo, xix–411 pages, glossary, index and 238 illustrations. Third edition, revised and enlarged. Philadelphia, P. Blakiston's Son and Co. $3.75 net.

In very compact and yet fully intelligible form, neatly printed and abundantly illustrated, Professor Youngken's book will be entirely satisfactory as a guide to the pupil in the general principles of botany, as well as for the student of its applications to pharmacy and science. The text is very comprehensive, embracing not only the general principles of structural botany, but the technic of preparing, mounting and examining specimens. As illustrations of typical forms of vegetable life, the life histories of a fern (*Aspidium felix-mas*), of a gymnosperm (*Pinus strobus*) and of an angiosperm (*Erythronium Americanum*) are treated in detail and abundantly illustrated. The cell life of the plant is then taken up, attention being given to the starches, carbohydrates, oils, resins and proteins, with the other ingredients.

An interesting chapter is that on botanical nomenclature, in which the principles of the binomial nomenclature are explained, and also the system of double authorities, which are so puzzling to the beginner. As an illustration of this system, Doctor Youngken gives the name of purging cassia, *Cathartocarpus Fistula* (Linné) Persoon, quoting from National Formulary IV. The reviewer is compelled to say that if the N. F. really uses the name Linné in connection with the plant, it is to be regretted, for botanists have universally agreed that the name of the great founder of the binomial system should be abbreviated to L.

There is an enormous amount of information in the book, and the abundance of excellent illustrations, the good type and good paper make it a most serviceable manual on the topic to which it is devoted. The style is clear, and the text is entertaining reading as well as instructive.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 95, Diagrams of Aeroplane Stability. 25 pages, diagrams. Washington, Government Printing Office, 1920. A study of the effect on longitudinal and lateral oscillations of an airplane of simultaneous variations in two resistance derivatives while the remainder of the derivatives are constant. The results are represented by diagrams in which the two variable resistance derivatives are used as coördinates, and curves are plotted along which the modulus of decay of a long oscillation has a constant value. The same type of analysis is also carried out for the stability of the parachute. In discussing the stability of a helicopter it is concluded that the gyroscopic effect on stability will be greater than in the case of the aeroplane.

Report No. 98. Design of Wind Tunnels and Wind-Tunnel Propellers, II. 10 pages, illustrations, plates, diagrams, quarto. Washington, Government Printing Office, 1921. The variations in velocity and direction of the wind stream were studied by means of a recording air-speed meter and a recording yawmeter. The work was carried on both in a one-foot diameter model tunnel and in a five-foot, full-sized tunnel, and wherever possible comparison was made between them. It was found that placing radial vanes directly before the propeller in the exit cone increased the efficiency of the tunnel to a considerable extent and also gave a steadier flow. The placing of a honeycomb at the mouth of the experimental portion was of the greatest aid in straightening the air flow, but at the same time this decreased the efficiency of the tunnel. Several types of diffuser were tried in the return air stream, but only a slight improvement resulted in the steadiness of the flow. Some experiments were tried on the effect of the shape of exit cone, and it was found that a straight cone in all cases gave the highest efficiency. The effect of placing a closed room about the model tunnel of the same proportional size as the building on the five-foot tunnel decreased the speed for the same power 14½ per cent. Several spinners were placed about the propeller in the model tunnel in the hope that they would give increased efficiency and a steadier flow, but in no case was there any improvement.

Report No. 104, Torsion of Wing Trusses at Diving Speeds. 8 pages, diagrams. Washington, Government Printing Office, 1920. It is the purpose of this report to indicate what effect the distortion of a typical loaded wing truss will have upon the load distribution. The case of high angle of incidence may be dismissed immediately from consideration, as the loads on the front and rear trusses are nearly balanced, and consequently there will be little angular distortion. A given angular distortion will have the maximum effect upon load distribution in the region of the angle of no-lift, because the slope of the lift curve is highest here, and it is here that the greatest angular distortion will occur, because the load on the front truss acts downward, while the load on the rear truss acts upward.

The RAF-15 aerofoil was chosen as most typical of present-day wing sections and serves for an illustrative example. This was combined with JN-4 wing truss, a biplane with overhanging upper wings. Starting with the assumption of a loading for a rigid structure, the wing truss and the deflections were calculated. The assumption of loading for the second trial was based upon the deflections as determined by the first trial. After several approximations it was possible to compute accurately the angular distortion at each panel point.

It was found that no great angular distortion occurred at panel points where there was adequate stagger bracing, but that it was considerable at the tip of the overhanging portion of the upper wing. In conclusion, it may be said that it is not worth the added complication to correct the load distribution on the conventional biplane for wing truss distortion, but that it would be highly advisable in the case of a monoplane, where the wires of the lift truss make an acute angle with the spars and where there can be nothing to take the place of stagger bracing. It would also be advisable in the case of the internally braced wing, where the relative deflection is likely to be high.

PUBLICATIONS RECEIVED.

The Gas World Year Book, 1921: 189 pages, quarto. London, Benn Bros., Ltd.

Exploitation du petrole par puits et galeries, par Paul de Chambrier. 106 pages, diagram, 12mo. Paris, Dunod, 1921.

U. S. Bureau of Mines: Bulletin No. 189, Bibliography of Petroleum and Allied Substances in 1918, by E. H. Burroughs. 180 pages, 8vo. Bulletin No. 191, Quality of Gasoline Marketed in the United States, by H. H. Hill and E. W. Dean. 275 pages, 8vo. Miners' Circular No. 27, Causes and Prevention of Fires and Explosions in Bituminous Coal Mines, by Edward Steidle. 75 pages, illustrations, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States, November, 1920, by W. W. Adams. 10 pages, 8vo. Technical Paper No. 255, Chlorination of Natural Gas, by G. W. Jones, V. C. Allison and M. H. Meighan. 44 pages, 8vo. Technical Paper No. 264, Preliminary Investigations of Storage-Battery Locomotives, Specifications, Laboratory Tests, Permissible Schedule, by L. C. Ilsley and H. B. Brunot. 35 pages, illustrations, plates, 8vo. Technical Paper No. 267, Stenches for Detecting Leakage of Blue-Water Gas and Natural Gas, by S. H. Katz and V. C. Allison. 22 pages, illustrations, 8vo. Technical Paper No. 275, Quarry Accidents in the United States During the Calendar Year 1919, by William W. Adams. 66 pages, diagram, 8vo. Washington, Government Printing Office, 1921.

U. S. Bureau of Standards: Technologic Paper No. 180, Causes and Prevention of the Formation of Non-condensible Gases in Ammonia Absorption Refrigeration Machines, by E. C. McKelvy, Chemist, and Aaron Isaacs, Associate Chemist. 10 pages, plate, 8vo. Washington, Government Printing Office, 1920. Price, 5 cents.

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The American Glass Industry.—The *Jour. Soc. Chem. Ind.,* in the final issue for 1920, gives some interesting statements by a British chemist who recently visited the more extensive glass industries in the United States. American efforts are directed principally to the production of glassware for the sale to people at large, optical glass and that intended for decorative purposes occupying a minor place. American glass works also generally specialize somewhat narrowly, one very large corporation, which has several factories under its control, making only wide-mouthed milk bottles. Automatic machinery is largely in use, the specialization permitting the application of such machinery to a much greater extent than when a great variety of articles is made. Some of the machines are strikingly productive, one of the Edward Miller type being able to turn out 11,000 tumblers per day. An automatic machine for blowing electric-light bulbs is capable of producing 100,000 bulbs per day. Glass tubing is drawn mechanically, a very successful machine having been invented for this purpose.

All these contrivances may seem typically American. Indeed, they are, for the Americans have shown in the glass industry such ingenuity and cleverness, such freshness of ideas and patience in working them out as to provide an object lesson for the rest of the world.

In conclusion, it may be said that on the actual glass-making side also development is becoming active largely through the work of scientific investigators. It is sufficient to refer to the development of really good selenium red glass, to the "day-light" lamp, and to Pyrex glassware and other glassware for cooking purposes.

H. L.

CURRENT TOPICS.

The Fuel Oil Problem.—This problem continues to attract attention from both the industrial and diplomatic point of view. Among the latest contributions to the former phase is a paper by W. A. White, read before the Northeast Coast Institution of Engineers and Shipbuilders, at Newcastle-upon-Tyne. Advance sheets of this paper have just been received.

After some allusion to the ancient use of bitumens and petroleums, and a discussion of the theories of origin, the author gives an account of the methods of obtaining them, stating that the discovery of their location is becoming more and more a science, as a result of geologic study. Interesting accounts are given of some of the great "gushers." In one of the Mexican wells, the drill weighing two tons was shot out of the well to a great height and landed forty-one yards from the well, almost at the feet of a photographer. This well yielded at one time 260,000 barrels in twenty-four hours.

The world's actual production in 1920 was about 700,000,000 barrels, of which Mexico produced 155,000,000 and the United States 445,000,000. Mr. White states that the potential capacity of Mexico, by which he means the amount that could be obtained by thorough exploitation, was, for 1920, 747,000,000 barrels. The average production in Mexico for that year was 1000 barrels a day for each well. There are twenty-five wells in Mexico that will flow 24,000 barrels per day, a total of 600,000 barrels. The known oil regions of Mexico are divided into three areas.

Many tables are given showing ratios of increase and other data. The total world deposits of petroleum are estimated at a little over forty-three thousand million barrels, which amount is about equally distributed in the two hemispheres. There are much larger deposits north of the equator than south, but this may be due partly to the greater land area in the former. No estimate can be made as to what may be under the sea.

The first tank steamer was built in England in 1885, presumably for German owners, though that is not stated, for it was called the *Glück auf*. It was 300 feet long and could steam at about 11 knots. The writer of this abstract had occasion to board this vessel as quarantine officer when it arrived at the port of Philadelphia. The United States and Great Britain, now the principal owners of tank steamers, owning respectively 41 per cent. and 40 per cent., the next largest being Holland with 3 per cent. The tonnage, however, under the stars and stripes is much greater than that under the British flag. A notable proportion of the American tonnage is under sail.

A large amount of information is given as to the method of obtaining, transporting, and storing oil, and some data in regard to testing it.

Although the United States is producing at present about two-thirds of the world output, yet over 100,000,000 barrels were imported to meet the consumption. In this fact lies the importance of the oil question to the United States.

H. L.

German Chemical Publications.—A drastic change in the mode of issue of the *Zeitschrift für angewandte Chemie* has been decided upon for 1921. Hitherto that journal—now coming into its thirty-fourth year—has consisted of three parts with separate pagination: (1) An "Aufsatzteil," containing original articles; (2) a "Wirtschaftlicher Teil," or economic section; and (3) the technical portion of the *Chemisches Zentralblatt*. These parts were issued twice weekly, as follows: (1), (2), and (3) were issued together at 200 mk. yearly, (2) at 50 mk., and (1) and (2) together at 120 mk. Partly on account of excessive cost and partly because the division of the abstracts into "pure" and "applied" was found to be unsatisfactory, it has been decided to discontinue the separate issue of the technical portion of the *Zentralblatt,* but all members of the Verein Deutscher Chemiker will be allowed to subscribe for the entire *Zentralblatt* at the same subscription rate, *viz.*, 200 marks, that is asked of members of the German Chemical Society, the price to non-members of these societies being 1000 mk. It is stated that the price of 200 mk. does not cover one-half of the cost of production and distribution, the deficit being made good by the Adolf Baeyer Society.

The *Z. für angewandte Chemie* will therefore in future consist of two parts only, an "Aufsatzteil," which will be modified to include reviews of progress in the different branches of pure and applied chemistry, and an economic portion, consisting of the existing publication *Die Chemische Industrie,* to be issued as a weekly supplement. The subscription price for the *Zeitschrift,* together with postage, etc., has been fixed at 56s. for England and colonies, $11.20 for the United States, and 127 fr. for France. (*J. S. C. I.,* 1920.)

In this connection it may be noted that a similar merging in the field of physics has taken place, the *Fortschritte der Physik, Halbmonatliches Literatur-verzeichnis,* and the *Beiblätter zu den Annalen der Physik* having been combined under the title *Physikalische Berichte,* issued under the joint auspices of the Deutsche Physikalische Gesellschaft and the Deutsche Gesellschaft für technische Physik. Twenty-four parts are to appear during the year, and the issues for 1920 are considered the first year, there being apparently no volume designation. The yearly subscription is fixed at 80 marks.

H. L.

The German Potash Industry.—At a meeting of the German Potash Syndicate held on October 14th it was stated that the convention prices made during the war had been renewed for 1921.

Production during the period January-September was 800,000 metric tons of pure potash (K_2O), an increase of 160,000 t. over the previous year; the increase was mainly due to the large agricultural demand in January and February last. Production costs have more than doubled, and the profit is barely above that for 1919. Although prices have not been raised since December, 1919, trade has been slack since May, except with adjacent countries, and the market in eastern Europe was at a standstill. The prohibition of the export of potash to Poland has closed a market which prior to the war consumed over 100,000 t. (K_2O) per annum. No decrease in the price of potash salts for agricultural purposes is probable, as the cost of production is still rising. (*J. S. C. I.*, 1920.)

H. L.

Radiation in Explosions of Hydrogen and Air. W. T. DAVID. (*Proc. Royal Soc.*, A690.)—A Hopkinson optical indicator was used to throw a spot of light on a revolving photographic film. From this record the temperature of the mixture at the time of explosion and during the subsequent period of cooling could be deduced. On the same film was the trace of a light-spot controlled by a platinum bolometer which received radiation from the gaseous mixture. This method makes it possible to follow continuously the changes that occur in a violent explosion. In the case of a "25.4 per cent. mixture of hydrogen and air" the temperature 0.17 second after explosion was found to be 2400° C. abs., and up to that time the total loss of heat by radiation was only .5 per cent. of the heat of combustion; at the end of .1 second, the corresponding quantities are 1920° C. and 7.7 per cent., and at the end of a whole second, 810° C. and 16.1 per cent. The proportion of heat lost by radiation decreases greatly as the strength of the mixture is weakened.

This paper is one of an extensive series of investigations being made in Great Britain upon the various phases of gaseous ignition.

G. F. S.

On the Use of "Vacuum Arcs" for Interferometry. J. GUILD, National Physical Laboratory. (*Proc. Phys. Soc. London,* vol. xxxii, p. 341.)—In the testing of the parallelism of the sides of slabs of optical glass it is often necessary to obtain interference between rays of light that have passed over quite different distances. In order that this may take place the light used must be monochromatic, and not only that but the line of light employed must be very narrow. Lately the green line of 5461A.U. proceeding from the mercury vapor lamp has been largely used. It is, however, found that the various types of this lamp are by no means equally good when the difference of path of the interfering light is large. The very bright, short lamps are not satisfactory, because they get hot, the pressure within them rises and the lines are in consequence broadened. The long lamps are rather inconvenient on account of their greater size. The author has devised a short lamp that in spite of its small volume gives a sharp line. Remembering that the vapor pressure within a closed space is governed by the temperature of the coolest part, he provides a large bulb over the positive electrode. This acts as a condensing chamber for the mercury vapor and thus keeps the pressure down. With it interference fringes are obtained with a maximum path difference in air of 10 cm.

G. F. S.

Reconstruction of Dwellings in the Devastated Regions of France. (*La Nature,* October 30, 1920.)—Data from the Ministry of the Liberated Regions.

Number of houses in the devastated zone in 1914.	1,204,862
Number of houses totally destroyed	293,733
Number of houses partly destroyed	362,755
UP TO JULY 1, 1920:	
Number of houses temporarily repaired	342,430
Number of houses completely repaired	292,470
Number of barracks built	33,454
Number of temporary wooden houses built	39,448
Number of houses built of materials harder than wood	20,645
Number of inhabitants lodged in:	
Repaired houses	645,116
Wooden barracks	126,771
Temporary wooden houses	144,189
Houses built of harder materials than wood	71,777

Thus nearly a million people are back in the devastated regions.

G. F. S.

Ostrich Eggs as Food. (*Scientific Am. M.*, December, 1920, p. 324.)—Mr. Gallichan, diet expert, who has been experimenting with ostrich eggs supplied by the New York Zoölogical Gardens, declares that the food value of the ostrich egg is about the same as that of the domestic hen's egg. The flavor is identical, and although the ostrich eggs contain less protein than meat, they have more fat and a fair amount of phosphorus and iron. One egg will make an omelet sufficient for thirty people.

Flow of Water. (*U. S. Geological Survey Press Bulletin No. 461,* December, 1920.)—" Second-foot," as defined by the Survey, is an abbreviation for cubic foot per second and is the unit for measuring the rate of discharge of water flowing in a stream 1 foot wide and 1 foot deep at a rate of 1 foot per second. It is generally used as a fundamental unit in measurements of stream flow.

" Second-feet per square mile " is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

An "acre-foot" is equivalent to 43,560 cubic feet and is the quantity required to cover an acre to a depth of 1 foot. The term is commonly used in connection with the storage of water for irrigation.

A flow of 1 second-foot equals 7.48 United States gallons a second, 448.8 gallons a minute, or 646,317 gallons a day. As a California "miner's inch" equals 0.187 gallon a second, there are 40 California miner's inches in 1 second-foot.

Progress of the American Dye Industry.—The Report "Census of Dyes and Coal-tar Chemicals, 1919, Tariff Information Series, No. 22," has been recently issued and may be obtained from the Superintendent of Documents, Washington, D. C., for 20 cents. From a summary of the report, the following data are taken. The production of dyes during 1919 was equal to, and possibly in excess of, our pre-war imports, with the exception of vat-dyes other than indigo. The manufacture of these vat-dyes requires long research, high skill, and large capital. The domestic production of indigo exceeded the 1914 imports, which is one of the notable achievements of the dye industry in this country. The average prices of the dyes made in 1919 were about the same as those of 1918, but the quality had been improved so that the consumer was getting more value for outlay.

The total production of dyes in 1919 was 63,000,000 pounds, being 38 per cent. more than the pre-war imports. Certain dyes have been manufactured in excess of domestic requirements, and considerable amounts have been exported, especially to Japan and China, but it must be borne in mind that such exportation has so far met with little competition from German dyes, and also that the domestic production vat and alizarin dyes was below the domestic requirements.

With the exception of anthracene, ample supplies of coal-tar crudes are now available in this country, and some progress has been made to increasing the supply of anthracene. The securing of adequate supplies of anthracene and anthroquinone will have a very favorable action on the dye industry. A decrease in total production of intermediates is noted because of the lessened demand for explosives, but seventy-six intermediates not heretofore produced in this country were furnished during 1919. It appears that in many cases the intermediates are sold at unreasonably high prices by German firms, because their true nature is concealed by fanciful names. The report, therefore, gives the true chemical name, and composition, with the trade name. American users will now be able to purchase these materials under their proper names. Data from Germany show that the output from German factories during 1920 was about one-third the pre-war output. H. L.

Present Status of the Merchant Marine of the Greater Nations.—In a paper by MAXWELL BALLARD, presented before the North-east Coast Institution of Engineers and Shipbuilders, at a meeting at Newcastle-upon-Tyne, in December last, advance sheets of which have lately been received, a comparison is given of the present status of the principal merchant marines, compared with two previous years.

Mid Year	1909	1914	1920
World Total Sea-going Tonnage	34,467,295	43,143,436	51,786,120
	Per Cent.	Per Cent.	Per Cent.
United Kingdom	47.9	43.8	35.1
Germany	10.75	11.9	.81
U. S. A.	4.49	4.81	24.1
Norway	3.67	4.54	3.82
France	4.20	4.46	5.72
Italy	2.79	3.32	4.27
Holland	2.62	3.39	3.44
Japan	3.1	3.96	5.78

Concerning this table, Ballard remarks as follows: "The three striking features are our loss of actual tonnage and pre-eminence of position, the elimination of Germany as a shipping power and the jump into second place of the United States. In every probability Germany's complete loss of place is temporary. There are already signs of efforts of recovery which are satisfactory in that there can be no revival of world trade of any account until Central and Eastern Europe settle down to steady work and production."

Attention is, however, called to the fact that the important point, the special subject of the paper is the freight tonnage; that is, the tramp steamers or cargo carriers, which meet in competition and rule the ocean freight market. Moreover, the only vessels now of account in this competition are steel steamers and motor vessels. Eliminating all other types, the figures are:

	1914	1920
Number of vessels	15,023	17,549
Tons	24,934,831	32,518,440

The last total includes steel coasting tonnage, which it was not possible to exclude accurately. A significant remark by the British engineer is: "Our interest centres upon our own position and that of the U. S. A., the really serious competitor, since the tonnage of both countries includes 60 per cent. of the total world tonnage."

A statement issued lately by Lloyd's Register shows that the aggregate tonnage now in course of construction in Great Britain is a little over 7,000,000 tons, 51.6 of which is under construction. The United States' share of total tonnage building has fallen from 37.7 per cent. to 18.2 per cent. To-day, the United Kingdom is building more than all the rest of the world combined, a position held by the United States during the late intensified shipbuilding campaign. The following data, taken from a recent issue of the Philadelphia *Public Ledger,* will be of interest in this connection:

"The status of world shipbuilding now, as compared with a year ago, is shown by the following table of gross tons of shipping under way at the two periods:

	Dec. 31, 1919	Dec. 31, 1920
United States	2,966,000	1,310,000
United Kingdom	2,994,000	3,709,000
Other countries	1,901,000	2,160,000
World total	7,861,000	7,179,000

"This table does not include figures from Germany.

"How Great Britain has been resuming its place as the world's shipbuilder is indicated in that of the 3,709,000 tons now under construction; 1,257,000 tons is for purchasers abroad."

The same issue also reports the arrival, in Berlin, of a commission in the Harriman interest, to effect a joint agreement with the Hamburg-American Company.

H. L.

British Dye Industry.—The British Parliament has passed an act prohibiting for ten years the importation of dyes from any source. Similar action was taken by proclamation in February, 1919, but in December following the order was declared invalid by a court. The problem of protecting the British industries along this line was discussed by Herbert Levenstein in an address before the London section of the Society of Chemical Industry (*J. S. C. I.,* 1920, xxxix, T. 317). The remarks of Lord Moulton are quoted as follows: "We have had peace in England, and never thought of danger, industrial or national. Even though there may not be another war, there is perpetual war going on industrially. It is based on what in the industrial world corresponds to war in the political world." Mr. Levenstein goes on to say that in the industrial war the struggle is for control of the "key industries," just as in political war the struggle is for the control of key positions. The German Interessen Gemeinschaft (I. G.) is using every effort to recover control of the old monopoly. It is stated, incidentally, that every toxic substance used by the Germans during the war, with insignificant exceptions, was made by the I. G. Mr. Levenstein's words as to the danger from poison gases are well worth quoting:

"So long as there is no counter to the rapid production of toxic substances in Germany, the world is not safe; the menace of the Rhine factories lies not only in their position but in the fact that they are unique. That the next war will begin as chemical war is certain." At the time of the signing of the Armistice, 70 per cent. of the casualties were due to gas.

H. L.

Microseisms. J. J. SHAW. (*Nature,* November 11, 1920.)—*Nature* now publishes from number to number brief, simple, interesting and authoritative discussions of scientific investigations and advances.

It has been known for a score of years that "no square yard of the earth's surface is ever at rest; an unending train of waves, waxing and waning in amplitude, are unceasingly coursing along the earth's crust and to unknown depths. The wave period ranges between four and eight seconds; the amplitude is between one fifty-thousandth and one two-thousandth of an inch, but with a wave-length of eight to sixteen miles. The speed of the waves is believed to be about two miles per second." Air tremors, the rocking of the observatory building in the wind and the swaying of trees, all were suggested as causes. It is now, however, known that they are real earth movements spreading over long distances.

In earthquakes the primary, the secondary phases and the long waves rising to a maximum make it possible to follow the course of the waves over the surface of the earth, but it has been difficult to identify individual microseisms. Without such identification it is impossible to study their propagation. The investigator succeeded in identifying tremors on recording instruments sixty feet apart. Emboldened by this, he extended the range until now he has two instruments two miles apart and producing records by which individual tremors can be singled out for study. The principal outcome of the studies has been to show that there seems to be no connection between the direction of the wind or any other meteorological condition and the direction in which the microseisms travel. They always arrive at the north station about .8 second before they reach the south station. It still remains to discover their origin and cause.

G. F. S.

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THE BEARING OF A SYNTHETIC DYE INDUSTRY UPON OUR NATIONAL WELFARE.*

BY

MARSTON TAYLOR BOGERT, A.B., Ph.B., LL.D.
Professor of Organic Chemistry, Columbia University, New York City.

INTRODUCTORY.

Statistics show that one out of every 1500 of our population is totally blind. The other 1499 of us are at least partially so. The one pathetic figure is doomed to complete his pilgrimage in utter darkness, forever excluded alike from the contemplation of what man has wrought through the centuries and from the enjoyment of all those matchless beauties of nature with which the Creator has so lavishly adorned this infinitesimal speck in His boundless universe. The other 1499 of us travel through life under the impression that we see everything around us. Yet are we blind in some one or in many important respects, for the layman is ever blind to the visions which open out before the imagination of the expert in any line of human endeavor. We cannot hope to see the picture with the eye of the artist, the building with the eye of the architect, or nature with the eye of the naturalist. In such matters, our blindness may be but partial or nearly total.

Thus the public still fail to see clearly the bearing of a well developed and diversified synthetic dye industry upon our individual and national welfare, and how vital it is to our progress

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and prosperity, or legislation would long ago have been enacted to protect and stimulate our domestic effort in this field and to safeguard it against threatened overwhelming by foreign dumping and competition.

To those who would raise the bogey of an American dye trust, I would reply that there is ample room in our country for small as well as large manufacturing units in this industry, as in the steel business for example. The existence of the U. S. Steel Corporation has not put the independent operators out of business, nor been to the disadvantage of the community.

But in world commerce, as in a world war, there is but one rational method of attack, and that is with an organization of a size and power commensurate with the undertaking. To attempt otherwise, will be as futile and as disastrous as were the efforts of the allies to fight the German war machine with a number of separate and insufficiently coördinated armies. The greatest and most powerful of Germany's industrial combinations is her giant dye combination. This huge consolidation has already called for additional capital, the life of the trust has been extended from the year 1966 to 2000, and its dissolution made more difficult by requiring a four-fifths, instead of a two-thirds, majority vote of the participating firms to unscramble it. Further, the Haber nitrogen fixation industry, with an authorized capitalization of half a billion marks, has been placed under the jurisdiction of this same dye trust. Control of the nitrogen supply means direct control of all explosives and of one of the most important constituents of all fertilizers, as well as indirect domination of many other industries. To compete in the world's markets with this giant organization, with the largest and finest equipment in the world, as the result of 40 years of intensive effort by thousands of eminent chemists and engineers, certain of our legislators appear to advocate a policy which will make it impossible for us to form any combination equal to the struggle. We have far less to fear from any American combination, the regulation of which is after all in our own hands, than from foreign domination of our industries, a control which Germany is now seeking to acquire, and toward which goal she is driving with characteristic thoroughness, persistence and concentration. Our grave danger lies in our failure to apprehend the deadly character of this menace to our safety, and in the short-sighted opposition of those textile manufacturers who cannot see that it is to their own selfish advantage to foster and encourage an American dye industry. If Germany once gains the upper hand in this key industry, we shall ultimately become a subject nation for, as Lincoln said, "no nation can long exist half slave and half free."

A FEW ILLUSTRATIONS.

What then is this synthetic dye industry that it is of such peculiar importance? Aside from the familiar uses of dyes themselves for coloring our flags, uniforms, clothing, and other fabrics, leather, paper, feathers, wood, and many other materials, are there other directions in which this industry ministers to the welfare of mankind and the progress of civilization? Let us look into the matter somewhat more closely, to find the answer to this question, and incidentally to gain a better appreciation of what it really covers.

When textiles, for example, are treated with solutions of certain chemicals, the fiber is permeated and penetrated and a more or less brilliant color imparted to it. The fabric so colored is said to be "dyed," and the material producing this effect is therefore known as a "dye" or "dyestuff." If the dyeing has been carried out properly, the fabric will be colored evenly throughout, and it will be impossible to remove the color by washing or by other solvents.

Painting, on the other hand, is merely a superficial coating of an article with a colored substance, termed a "pigment," suspended in a suitable liquid "vehicle." Almost any colored substance may serve as a pigment, and various dyes which combine with mineral salts to highly colored solids, called "lakes," are extensively used for this purpose, in addition to the more common mineral pigments not lakes. The usual vehicle for paints is linseed oil, since this on drying gives a tough weather-proof skin, retaining the pigment as an even coating.

Many of these dyes and lakes also form the basis of inks and ink powders.

Dyes are often divided into natural and artificial. The dyes of our ancestors were all natural products, and the proposal to manufacture artificial dyes was received with amusement and scorn, as though man-made products could ever hope to displace nature's greatest coloring agents, like madder and indigo. The more pious of the community even referred to such undertakings as sacrilegious. Nevertheless, the chemist patiently continued his investigations and was soon able to show clearly that it was only certain constituents of the plants which possessed this tinctorial power and that the rest was either wholly useless or even objectionable. Then came the synthesis from anthracene of alizarin (in 1868), the active tinctorial constituent of madder, which was soon followed (in 1870) by the synthesis of indigo from benzole.

Chemistry has not only determined the actual tinctorial constituents in many natural dyes and reproduced them artificially, but it has also shown the way to prepare tens of thousands of other dyes which, so far as we are aware, are not found in nature. Compared with the industry of the artificial dyes, that of the natural dyes is to-day relatively insignificant. Long and patient study of the intimate chemical nature of these synthetic dyes has enabled the investigator to determine in most cases the particular combinations of atoms upon which this tinctorial power depends and the effect produced upon the shade by the alteration of these groups or the insertion of others, so that the expert can now tell in advance, if shown the molecular formula or structure of the dye, just what color it is likely to produce upon cloth. The chemist has succeeded in producing artificial dyes of every conceivable shade of the rainbow, at such a low price, of such purity, fastness and beauty, that the natural dyes either have been driven from the market, or the best of them (like alizarin and indigo) are now made synthetically. Logwood is the most important exception to this, although small amounts of gambier, turmeric, orchil, persian berry extract, saffron, madder and other natural dyes are still imported. The total value of the natural dyes imported in the year 1919 was $1,247,188, while the artificial dyes and color lakes made in this country the same year were worth $71,778,819.

Practically all of the artificial dyes are prepared synthetically, *i.e.,* built up step by step from simpler substances, somewhat as one might erect a house by laying a suitable foundation and then constructing the different stories upon it one at a time, and they are hence properly designated as " synthetic dyes," synthesis being the reverse of analysis.

This is simply and quickly demonstrated by the production of a dye from two colorless substances (Naphthol Orange); or, by heating together salicylic acid and wood alcohol, in presence of a little sulfuric acid to assist the reaction, a wholly new compound results, identical with the main constituent of the natural oil of wintergreen and the one to which it owes its characteristic odor and taste, and which is therefore known as the synthetic oil of wintergreen. These are typical syntheses. To prove that natural oil of wintergreen really is a combination of the two substances stated, it can be heated with caustic soda solution, which treatment resolves it again into salicylic acid and wood alcohol. This is an analytical process; in this particular case called a "proximate" analysis, because each of the two substances obtained can be broken down into still simpler substances by suitable treatment.

The vast bulk of our synthetic dyes are all built up from five simple initial materials, the so-called "crudes," which are familiar to all of you. They are the following—benzole, toluene, naphthalene, anthracene and carbolic acid. Five others, less common but which yield a number of important dyes, are xylene, methyl anthracene, phenanthrene, cresylic acid and carbazole. As all of these ten crudes are found in the tar obtained when coal is heated for the production of illuminating gas or for the manufacture of coke, and as this material constitutes their chief source the resulting dyes are generally known as "coal tar dyes," and this appellation has been extended so as to be synonymous with "synthetic dyes," irrespective of whether actually made from coal tar or from crudes obtained from other sources.

These crudes then represent the foundations upon which we can build an endless variety of structures, of one or several stories. The building operations of the chemist differ somewhat from those of the contractor erecting a house, in that the chemist ordinarily puts up his structure one story at a time, each one being complete in itself, and it may be that he will run it up ten or fifteen stories before putting on the roof. At many of these intervening stages, it is entirely possible for him to change his mind and complete the building as a drug, a photographic developer, a perfume, or something else instead of a dye. These intermediate products therefore, standing as they do midway between the crude initial materials and finished products, are known conventionally as "intermediates," and from our ten crudes, approximately 300 intermediates are manufactured commercially for the production of the 1000 synthetic dyes now found in the world's markets.

According to the recent census conducted by the U. S. Tariff

Commission for the year 1919, there were 214 manufacturers of dyes and intermediates; 116 concerns engaged in the manufacture of intermediates, and 155 in the production of finished dyes and other synthetics, 90 of them turning out only dyes (63,402,194 pounds, valued at $67,598,855).

Those engaged in other lines than dyes were as follows:

Number of firms.	Goods mfd.	Pounds mfd.	Value of output.
34	Color lakes	7,569,921	$4,179,964
31	Medicinals	6,777,988	7,883,071
10	Photochemicals	335,509	1,059,340
9	Flavors	610,825	1,318,654
6	Phenolic resins (5) and tannins (1)	3,794,534	2,381,358
6	Perfumes	41,419	164,302

Considerable progress was recorded in the United States dye industry during 1919. The list of intermediates was augmented by 76 not previously manufactured here, bringing our total up to 216, and there was a considerable increase in the output of the higher grade ones. In the quality and quantity of finished dyes, there was also a gratifying growth as compared with 1918, the total production being 38 per cent. greater in amount than our total imports of dyes for the fiscal year 1914. In fact, we have ourselves already become exporters of dyes, our exports for the nine months ending September 30, 1920, having been valued at $26,032,389, which exceeds the total value of dyes imported during the fiscal year 1914. Of this amount $17,038,235 represented aniline dyes, $2,321,090 logwood extracts, and $6,673,064 other dyes. To be sure, an important factor in this achievement was the absence of foreign (especially German) competition, but it shows none the less the rapid strides made in the development of our domestic industry.[1]

Our 216 intermediates in 1919 were derived from the following crudes: benzole = 55, toluene = 47, xylene = 4, naphthalene = 66, anthracene = 10, carbolic acid = 26, other crudes = 8.

Perhaps it will help us to visualize the ramifications of this industry more clearly if we alter our simile and liken our initial materials to a grove of trees, each one growing out of the mother earth of original sources (coal tar, for example), the branches and smaller twigs representing the intermediates and the fruit the final product, be it dye, drug, perfume or something else.

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[1] The dyes exported included sulphur dyes, mainly blacks and browns; direct cotton dyes, chiefly blacks, greens, blues and reds; acid dyes, especially scarlets and oranges; basic dyes, largely malachite green, methyl violet and magenta; and synthetic indigo. Obviously, a large export trade should be an important factor in enabling the manufacturer to supply the home consumer at a low price.

In addition to the 216 intermediates manufactured for commercial use, 119

Let us step a little closer then and examine these trees somewhat more carefully, so as to ascertain the kind of soil upon which they grow, their relative size and spread, the nature and extent of this development, and the character of the fruit. In the brief time available, this examination must necessarily be hasty, superficial and incomplete, but it will at least give us a better idea than the hazy outline we have hitherto seen only from a considerable distance.

BENZENE (BENZOLE).

The first tree we come to is labelled Benzene, but is also called Benzole. Although benzene is the correct chemical designation, the name is unfortunate since there is a totally different compound, obtained from petroleum, which is known as "benzine," and this often leads to confusion. We shall therefore use the term benzole in what follows. In its size, development, and in the beauty and variety of its fruit, this benzole tree is one of the monarchs of the whole grove.[2]

The total production of all grades of benzole for the year 1919 is placed by experts at 63,000,000 gallons; of which about 53,000,000 gallons went for motor fuel; 5,500,000 gallons were produced in the form of pure benzole, and were consumed mainly by the dye industry; and 4,500,000 gallons were sold as 90 per

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other intermediates and special organic chemicals were produced for research work. These totalled 2291 pounds and were valued at $23,333.

With the signing of the armistice, the production of intermediates and dyes used mainly for military purposes (explosives, toxic gases, dyes for uniforms, etc.) declined sharply. The intermediates most seriously affected were carbolic acid (referred to beyond), monochlorobenzene (80 per cent. drop), nitro naphthalene (36 per cent. drop), dimethylaniline (16.5 per cent. drop), diphenylamine and dinitro toluene among those used for explosives; and m-dinitrobenzene and m-nitraniline, manufactured for wool dyes (Alizarin Yellow GG and R) for army uniforms, and m-toluylene diamine for sulphur browns for cotton khaki uniforms.

[2] The output of benzole for the year 1918 was 52,240,758 gallons, valued at $14,627,743. This was obtained from the following sources: Tar distilleries, 3,015,848 gallons ($994,161); coke ovens, 44,804,900 gallons ($12,341,779); gas houses, 4,420,010 gallons ($1,281,803).

cent. benzole for use as solvent in the paint, rubber and other industries.[3]

Thus there appears to be an ample supply of benzole in our country to permit considerable expansion of our dye production, unless other industries requiring it in large amount very markedly enlarge their demands also. The question is an important one for the dye industry, as benzole is in many respects the most fundamental of all the crudes, all the rest of which, by the way, can be made from benzole in the organic laboratory, although not commercially.

The first branch which leaves the parent trunk of benzole, starts out under the name of nitrobenzole and, after one or two minor offshoots, continues as aniline, from which latter a most luxurious myriad growth springs. This nitrobenzole-aniline branch is not only the largest and most far-reaching of the entire tree, but it also has the most wonderful development and the most exuberant foliage.

Nitrobenzole is made direct from benzole by warming it with a mixture of nitric and sulfuric acids, the process being called nitration. The product is a pale yellow oil when freshly prepared, of a strong and rather rank bitter-almond odor; in fact, it was first used as a cheap perfume, under the name of oil or essence of mirbane, and small amounts are still occasionally used for that purpose. To a limited extent also it finds use in the manufacture of explosives. The great bulk of it, however, is so treated as to compel it to exchange the oxygen it contains for hydrogen, a process which the chemist terms reduction, and the nitrobenzole is thus reduced to aniline. This nitration and reduction for the manufacture of aniline are carried out mainly by the dye plants, since aniline is one of the most important of dye intermediates.[4]

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[3] During the same year, we exported 76,592 barrels of coal tar, of an average net weight of 500 pounds per barrel, which would have yielded about 32,000 gallons more of benzole. As only 56.2 per cent. of our coke was produced in by-product ovens, large additional amounts are obtainable from this source by replacing all of the remaining wasteful beehive ovens by modern by-product ones. Increased amounts are also available from other sources whenever an enhanced price makes it an object.

[4] The nitrobenzole produced in the United States during 1919 amounted to 42,544,017 pounds, valued at $5,899,837, and in addition 21,513 pounds were imported. The aniline manufactured the same year amounted to 24,345,786 pounds, worth $5,932,536; and 1,446,909 pounds of aniline salts, sold for $359,296, besides which 21,273 pounds of these salts were imported (from England).

As the great majority of all the early coal tar dyes owed their origin, either directly or indirectly to aniline and very closely related compounds, the name Aniline Dyes has been widely current as synonymous with synthetic dyes, and still persists, although no longer appropriate except in restricted sense.

To give some idea of our 1919 production in the field of dyes derived from anilines, the following figures are cited:

	Pounds	Valued at
Indigo (including its sulpho acid)	10.563.494	$6,327,443
Nigrosine (both water- and alcohol-soluble)	2,006,316	1,232,965
Methyl Violet	574.436	1,403.179
Induline (both alcohol- and water-soluble)	566,905	318,727
Metanil Yellow	477.143	787,110
Methylene Blue	465.992	1,410,760
Bismarck Brown Y	412,574	417,276
Gallocyanine	365,243	1,105.346
Chrysoidine Y	314,581	326,223

It may surprise some of my hearers to learn that indigo is now generally manufactured from aniline, and that the amount of natural indigo imported is relatively negligible (46,878 pounds in the first six months of 1920). Indigo is probably the oldest dye known to man. It may be difficult to prove that the blue room in Noah's ark was decorated with it when he took his historic cruise, but it is scarcely to be doubted that Joseph's coat of many colors owed no small part of its brilliance to this common article, for indigo has been found in the pyramids of Egypt, in the ruined cities of Babylonia, and in the shops and houses of Pompeii. It is a product of many different plants, occurring in many countries, and has for untold ages been used by savage and civilized alike. And yet, at the present time, indigo is produced in commercially important quantities, from its natural source, in but two sections of the globe, the Bengal region of India, and Central America (Salvador). These are the last strongholds of an industry that was once world-wide. The chemist has succeeded in improving upon the leisurely and complicated processes of nature to such an extent that synthetic indigo is now produced rapidly and economically from aniline in any desired amount and of higher purity than the natural article. The indigo farmer, like the madder farmer and the cochineal raiser, will ultimately be compelled to turn his land to other crops—possibly to the raising of much needed foodstuffs, in the case of India.

That the chemist can in a few minutes produce what the indigo plant requires a whole season to do, I will prove by making some indigo before your own eyes from a few simple chemicals. (Experiment.)

In our country, indigo ranks second to Sulphur Black in point of consumption, but it is first in world consumption on account of the large quantities used in China. Our production in 1919 exceeded our pre-war annual imports and our domestic needs, so that large amounts were exported. The du Pont Co. states that it can supply the entire requirements of the country from the output of its own plant.

The only dye rivalling indigo in the estimation of the ancients was Tyrian Purple, or the Purple of the Ancients, a dye so expensive that in the reign of Diocletian (300 A.D) one pound of purple wool cost about $240, which would make the dye itself worth approximately $5000 a pound. Its use became identified with royalty, and led to such expressions as "porphyrogenitism," "born to the purple," "royal purple," and the like. The dye was obtained from certain species of sea snails (Murex), which on decomposing formed this precious coloring material. It occurs in a small sac behind the head, and forms a drop of whitish liquid when first removed. On exposure to the air and light, it changes first to green, then blue, and finally purple. If set by an alkali (soap), it becomes a fast crimson, such as ecclesiastical dignitaries still wear. Great heaps of these snail shells are still to be found outside the ancient coast cities of the Mediterranean. After the fall of Tyre, the secret of the source of this dye appears to have been lost for centuries. In 1909, Professor Friedlaender gathered 12,000 of these mollusks and by very careful work succeeded in getting a total of 1.5 grams of the coloring material, which he investigated carefully and found to be identical with a dye prepared five years previously by Sachs, but not put upon the market because of its inferiority to others already available. The interesting thing about the nature of the dye is that it is a derivative of indigo, containing two bromine atoms in place of two of the hydrogens of ordinary indigo. It is now frequently made in the organic laboratories of our universities, and I have had several of my own students prepare it at various times.

It is perhaps worth noting in passing that aniline owes its name to its having been obtained first from indigo, the Arabic name of which was "anil," or "al-nil," that is "blue stuff," by distilling the latter with caustic soda, but it took chemists forty years to find out how to produce indigo from aniline.

In 1856, the late Sir William Perkin, while endeavoring to devise a method of preparing quinine synthetically, oxidized some commercial aniline oil, and obtained instead a purplish dye, which he called "mauve," and which was the first of the modern synthetic dyes. Perkin was quick to recognize the importance of his discovery, and this became the starting point for the wonderful synthetic dye industry and the origin of the name "aniline dyes." Perhaps you would like to see this historic experiment repeated. (Experiment.)

In the case of many of the dyes described beyond as prepared from naphthalene, carbolic acid, etc., an aniline derivative is often present as one of the components of the initial mixture. Certain of the aniline dyes, in the form of lakes, are employed as pigments, as already mentioned, and a considerable tonnage of such lakes is manufactured for this purpose; others form the basis of inks and ink powders.

A further and very important use for some of these dyes is as bacterial stains, in the diagnosis of various diseases; and occasionally they are used direct as bactericides in attacking sundry ailments.

But dyes are not the only fruit we find this aniline branch bearing. If we follow out certain lateral branches from it, we shall come upon products which are even more important, the synthetic drugs, upon which our health and even our lives may depend in times of critical illness. Among these you will find such well-known medicinals as acetanilide (antifebrine),[5] antipyrine, arsphenamine (salvarsan), neo-arsphenamine (neo-salvarsan), cinchophen (atophan), and many others.

The history of synthetic dyes is being repeated in the case of synthetic drugs. As we are all aware, the market during the past decade has been flooded by what are dubbed the "newer remedies," most of them derived from coal-tar dye intermediates, and practically all of them produced in the organic laboratory, where they were built up for the sole object of obtaining certain definite physiological results. They represent the efforts of the chemist to develop a really scientific materia medica, and the slow but sure progress in this direction is not only highly interesting, but means much to suffering humanity.

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[5] Our production of U. S. P. acetanilide in 1919 was 918,795 pounds, valued at $440,066.

It was early recognized that the physiological action of various plants was due to certain definite chemical compounds which they happened to contain, and the first task of the chemist was to isolate, identify and study these "active principles." This study led quite naturally to attempts to reproduce artificially either these substances themselves or others of analogous structure, and to determine the particular atomic complexes responsible for the physiological effects observed. Then taking the knowledge thus gained, the chemist cut loose entirely from natural products and set about building up in his own laboratory new bodies which should contain these physiologically potent groups, and his activities in this direction are reflected in the innumerable new drugs constantly appearing. A steadily brightening light is being shed upon the connection between chemical structure and physiological action, and the physician now has at his command powerful healing drugs, which, so far as we know, are not duplicated in nature.

The natural substances are built up in the plant to play a definite rôle in the structure and life of those organisms, and the fact that they happen to be of therapeutic value when taken into the human system is purely fortuitous. The synthetic remedies, on the other hand, are synthesized with the specific object in view of producing substances which shall contain physiologically active groups, or so to modify a compound as to enhance its therapeutic value. It is not necessary, therefore, to construct the entire complicated molecule of an alkaloid if the same results can be secured with simpler structures, and this has been demonstrated already in many instances. In the case of the natural remedies again, other substances are frequently present which exert undesirable and even dangerous side effects. The great advantage of the synthetic drug then lies in its being a pure chemical individual, instead of a mixture of varying and uncertain content. This permits exact determination of its physiological action, accurate dosage, easy detection of adulteration and greater stability.

The life functions are essentially chemical, the cell being the laboratory, and the isolation and chemical identification of the substances formed by the organism in its endeavor to protect itself against the inroads of different diseases should show to the chemist the type of compound to be added in order to support and stimulate this action. After the drug leaves the hands of the organic chemist, it is the task of the physiological chemist to ascertain just what happens to it in its course through the system, and to discover if possible which one of its numerous transformation products or ions is really the one upon which its therapeutic value depends. The time is surely coming when it will be necessary only for the physician to state just what effects he wishes to produce, and the chemist can build up for him a compound which will do all that is required and be free from unpleasant side or after effects, much as the child would build up a new kind of house with the same old blocks. This probably seems to you an extravagantly optimistic view, but if you will consider for a moment what has already been accomplished in this direction I am sure that you will share my enthusiasm. It takes years to solve such problems, of course—von Baeyer worked twenty years upon the molecular structure of indigo, but he finally solved the mystery.

The popular superstition that the medicinal value of a pure chemical compound is modified in some obscure but positive manner by the source from which it is derived, is as old as the hills. The famous "English drops," a drug which really consisted of nothing but ammonium carbonate with a little ethereal oil, sold for high prices up to the close of the 17th century, because it was stated by some that the ammonium it contained was obtained by the dry distillation of silk, while others even went so far as to maintain that it was prepared by distilling five pounds of the skulls of persons who had been hanged (or who had come to some other unnatural end) with two pounds of dried vipers, hartshorn and ivory. We smile, and yet this same kind of superstition still retains its hold upon the community and has materially retarded the introduction of really valuable synthetic remedies.

In addition to drugs and dyes, some of our important photographic developers owe their origin to nitrobenzole and aniline. Such are hydroquinone and metol,[6] for example; and at the outset of our participation in the war, the shortage of metol was felt seriously, for there is little use in having photographs made of the enemy's lines from airplanes or captive balloons, unless suitable chemicals are available to develop and fix the picture.

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[6] Our 1919 production of hydroquinone was 272,329 pounds, valued at $552,087; and of metol, 59,024 pounds, valued at $508,434.

Among the more fragrant blossoms of the benzole tree are the synthetic perfumes. These include one of the constituents of rose perfume (phenyl ethyl alcohol), which is present also in the odor of the orange blossom, one of powerful rose-leaf aroma, some of geranium-leaf (diphenyl oxide) and of syringa-like (acetophenone and methyl acetophenone) odors, and many others of delightful fragrance.

The same tree that bears these beautiful products bears also some of the deadly toxics used in the late war; such, for example, as the famous "sneeze gas" (diphenylchlorarsine) with which the Germans filled their blue cross shells, and which killed many of the allied soldiers when it was first employed, for the older allied masks did not give complete protection against it.

Other dangerous products are the various explosives derived from benzole, such as the more highly nitrated benzoles, T. N. A. (tetranitroaniline), Tetryl (tetranitromethylaniline), and picric acid. It is interesting to observe that the latter is really growing on a graft from the carbolic acid tree.

Aniline provides also one of the best stabilizers (diphenylamine) to protect smokeless propellants against deterioration, and yet this substance itself becomes a powerful explosive when sufficiently nitrated, or it may, on the other hand, be converted into some very beautiful dyes.

Like carbolic acid, aniline will unite with formaldehyde to a resinoid. The properties of the product are not such as to make it of any commercial service, but the reaction is such a simple one to carry out that we can do it here on this table. (Experiment.)

Even these manifold uses of aniline and other benzole derivatives do not begin to exhaust the list. Aniline and divers compounds produced therefrom find application also as accellerators in the vulcanization of rubber (*e.g.* thiocarbanilide, m-phenylene diamine, nitrosodimethylaniline), and yet further uses might be cited before the story was complete.[7]

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[7] Other important benzole intermediates which should be mentioned are the following: m-dinitrobenzole, m- and p-nitraniline; the chloro and bromo benzoles, used during the war for the manufacture of carbolic and picric acids, for

TOLUENE (TOLUOLE).

Having examined the benzole tree somewhat critically, let us turn to the next tree in our coal-tar grove. The label on it reads "Toluene, or Toluole," and it is the next older brother to benzole, belonging in the same family and having all the family traits and characteristics, plus a few peculiarities of its own. In size and development it is almost as imposing as benzole.

As toluene is the raw material for the manufacture of the important explosive T. N. T., every effort was made during the war to increase our output of this crude by installing additional by-product coke ovens and by "stripping" illuminating gas, as well as by other processes, with the result that for the calendar year 1918 our total output was over 12,000,000 gallons, valued at over $18,000,000.[8] With the cessation of the war the demand and price fell precipitately, the production of pure toluene for 1919 being estimated at about 1,000,000 gallons, practically all of which went to the manufacturers of dyes, dye intermediates and medicinals.

Let us consider briefly some of the intermediates and final products which owe their origin to this crude.

As in the case of benzole, our toluene can be nitrated, giving nitro toluenes, which on reduction yield compounds (toluidines) similar in properties, utilization and possibilities to aniline. The nitration products include the T. N. T. noted above, other explosives, and one of the best of the synthetic musks, of powerful musk-like odor but, so far as we now know, not identical with the odoriferous constituent of the real musk from the musk deer. The toluidines yield dyes, drugs, etc., much in the same manner as

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dinitrophenol, and the parazole explosives; the sulpho benzoles, for carbolic acid and resorcinol and their derivatives.

Our 1919 production of some of these was:

	Pounds	Valued at
Monochlorobenzole	4,116,666	$623,875
Dimethylaniline	3,559,654	1,941,152
m-Dinitrobenzole	2,280,282	548,302
Thiocarbanilide	2,268,375	802,575
p-Nitraniline (and sulphate)	1,310,658	1,388,627
Benzidine base	1,084,922	1,370,393
Sulphanilic acid	1,023,861	243,656

[8] The 1918 production totalled 12,321,017 gallons, of a value of $18,255,978; divided as follows: Tar distillers, 1,596,353 gallons ($3,044,890); coke ovens, 8,861,948 gallons ($12,709,460); gas houses, 1,862,716 gallons ($2,501,628).

aniline, but having already followed out such a branch in the case of benzole, let us take a different one here—one inscribed "Chlorotoluenes."

When toluene is treated with chlorine, under proper conditions, some of the hydrogen it contains is driven out and the chlorine takes its place, new compounds being formed.

One of these (benzyl chloride; 1919 production 720,953 pounds, worth $166,182) is used for the manufacture of dyes known as Benzyl Violets, and is also the source of one of the most potent lachrymatory gases of the war (brombenzyl cyanide), which was prepared by acting upon it first with cyanide of potassium and then subjecting the product so obtained to the bromine extracted from the brine wells of Michigan or of the Ohio River valley. Strange as it may seem, if instead of using bromine we carry this intermediate product through a different series of reactions, the result is a wonderfully fragrant perfume possessing in high degree the delicious scent of the hyacinth and narcissus, and entirely free from any lachrymatory effect.

Another one of our chlorination products from toluene (benzal chloride), when boiled with lime gives the chief constituent of the oil of bitter almonds (benzaldehyde), which is better than the natural product in certain respects and is used as a substitute for it (1919 production of benzaldehyde, 518,634 pounds, valued at $403,109). From this synthetic oil of bitter almonds, many compounds are prepared which contribute to the happiness of our people. One of these is the popular dye called Malachite Green, of which we made 560,301 pounds in 1919, valued at $1,827,474. Another is synthetic oil of cinnamon, identical with the substance present in the natural oils of cinnamon and cassia, and to which they owe their characteristic odor and taste. It is consequently sold as a substitute for the natural article, and the value of the natural oil is decided commercially by the percentage of this substance present. Other products obtained from synthetic oil of bitter almonds include certain of the perfume substances actually present in orange blossoms, jasmine, tuberose, gardenia and ylang ylang, as well as purely artificial compounds of the odor of moss roses, of hyacinths and of narcissus.

When boiled with a strong solution of caustic potash, our oil of bitter almonds changes to two other bodies. One of these is benzoic acid, of which I shall have more to say in a moment. The other is a mobile colorless liquid, related chemically to ordinary alcohol, and which is itself the source of drugs and perfumes. These two products can be made to unite to a totally different one (benzyl benzoate), which is a heavy oily liquid and which has the valuable property, when added to the "dope" or varnish for airplane wings, of causing this coating to dry slowly and harden without cracking, and it is hence called a " restrainer."

Whereas, as just described, one of the products obtained by the action of chlorine upon toluene yields oil of bitter almonds when boiled with lime, there is a third one of these chlorination products (benzo trichloride) which when treated in the same way gives benzoic acid instead, and this is one of the chief commercial methods for the manufacture of this important compound (1919 production, 699,108 pounds = $534,832). The synthetic product is identical with that obtained from storax, balsams of Peru or Tolu (whence the name toluene), or from other natural sources. It finds employment as a food preservative (in the form of its sodium salt), and in the manufacture of dyes and perfumes, as well as for the production of such drugs as procaine (novocaine),[9] anesthesine, barbital (veronal), chloramine-T and dichloramine-T.

Another branch from our toluene tree is marked " Sulpho derivatives," and it bears that remarkable sweetening principle, " Saccharin," four pounds of which will sweeten as much coffee as a ton of ordinary sugar. It is the sweetener customarily used by those people suffering from diseases which would be aggravated by cane sugar.

The 1919 production of toluene intermediates comprises the following as the larger items:

	Pounds	Valued at
o-Nitrotoluene	1,360,599	$312,416
p-Nitrotoluene	1,263,056	704,750
o-Toluidine	1,002,982	503,020
p-Toluidine	575,841	600,267
Dinitrotoluene	746,266	264,388
m-Toluylene diamine	493,544	504,063

The toluene dye manufactured in largest amount appears to have been Bismarck Brown 2R, of which we turned out 631,308 pounds, worth $659,332.

XYLENE (XYLOLE).

Standing next to benzole and toluene, and members of the same family, is a group of triplets, the three xylenes, whose first names are Ortho, Meta and Para. Like other triplets, they are so fond of one another that it is not easy to separate them, and as they are so much alike in appearance and general behavior this is not necessary in many cases. They are found in that fraction of coal tar sold under the name of "solvent naphtha" which, as its name suggests, finds its major use in industry as a solvent.

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[9] In 1919 we produced 3448 pounds of procaine, valued at $330,334.

Although the source of many beautiful dyes, and of other useful products, and possessing still greater possibilities than either benzole or toluene, the xylenes, largely because of the difficulty of separating them, have not achieved anything like the same development, and we will not tarry longer to examine them more closely.

NAPHTHALENE.

Turning now from the benzene family, we see another huge tree of widespreading habit and massive trunk, but of somewhat different appearance. Its tag reads "Naphthalene." It is brilliant with a fruitage of dyes of every conceivable shade, with only here and there a drug, perfume, or explosive.[10]

It is worth noting that we use this crude, in the form of moth balls, to protect against insect ravages textiles which may be dyed with naphthalene dyes.

Not many years ago, naphthalene was the starting point for the manufacture of synthetic indigo, but it is now more economical to use aniline for this purpose. One of the intermediate products in this older process, when combined with wood alcohol, is converted into a perfume substance which is found in the flowers of the orange, jasmine, tuberose and narcissus.[11]

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[10] In 1918 we produced 40,138,092 pounds naphthalene from tar distilling operations, valued at $1,281,440; 16,087,498 pounds, worth $655,232, from by-product coke ovens; and 545,003 pounds, worth $15,497, from gas houses; or a total production of 56,770,593 pounds, valued at $1,952,169.

In 1919 the output fell to approximately 18,000,000 pounds, of which, roughly, two-thirds went to the manufacture of dyes, intermediates and related products, and the remainder chiefly to moth-balls.

At the termination of the war, considerable stocks of naphthalene had accumulated as by-product in our strenuous efforts to increase our supplies of toluene. Not only was less tar distilled in 1919, for reasons already cited, but the manufacturers fearing overproduction, in the tar that was distilled left more naphthalene in the creosote oil, so as to run up the yield of the latter, which was then in great demand. On removal of export restrictions, large orders for naphthalene dyes and intermediates suddenly made their appearance, causing an acute shortage of naphthalene in the latter part of 1919 and the early portion of 1920, and resulting in the importation of about 11,000,000 pounds in the first nine months of 1920.

ANTHRACENE.

Another very important crude is Anthracene. Although as yet not the parent of such a numerous crop as either benzole, toluene or naphthalene, it is however the origin of some of the finest and fastest dyes in the world to-day, particularly in the class of vat dyes, a group to which by the way indigo belongs. The peculiarity of vat dyes is that on reduction they yield a soluble form of dye which thoroughly permeates and penetrates the fiber, and which on oxidation in the air separates the dye itself in an insoluble form within the fiber, extremely fast to light, washing and bleaching. As the operation is generally carried out by steeping the goods in a vat filled with the reduced dye, the process is termed vat dyeing.

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[11] Among the intermediates requiring a specially expert technic, it is encouraging to find that in 1919 five firms successfully manufactured the so-called "gamma acid" (aminonaphthol sulpho acid, 2:8:6), their combined output amounting to 155,025 pounds, valued at $667,360. From this were synthesized 485,046 pounds of Oxamine Black BHN, worth $1,321,362, a most useful direct black, which can be developed on the fiber, as well as other valuable fast direct cotton dyes, and Zambesi Black, an important dye for union hosiery.

Among the naphthalene intermediates produced in 1919, the following are cited:

	Pounds	Valued at
Beta naphthol, tech.	4,835,778	$2,365,804
Aminonaphthol disulpho acid (H acid)	3,837,534	5,081,460
Nitronaphthalene	2,774,516	368,500
Naphthionic acid	2,008,189	1,235,742
Alpha naphthylamine	1,552,828	632,587
Naphthylamine trisulpho acid, 1:3:6:8	1,418,560	867,005
Naphthol disulpho acid, 2:3:6 (R acid)	1,008,007	721,341
Aminonaphthol sulpho acid, 1:2:4	837,384	808,894
Alpha naphthol	135,025	136,833
Beta naphthylamine, crude	99,597	167,590

Of the naphthalene dyes produced in large amounts during 1919, the following statistics are pertinent:

	Pounds	Valued at
Direct Deep Black EW	7,250,007	$7,521,343
Algama Black 10B	1,877,860	2,757,443
Benzo Blue 2B	1,380,335	1,386,291
Orange II	1,133,925	717,199
Congo Red	873,734	979,285
Salicine Black U	739,372	923,888
Eriochrome Black A	686,710	933,677
Ponceau 2R	552,680	439,515

Unfortunately, anthracene is one of the few really important crudes of which we still lack an adequate supply, and this is one reason why these dyes have been among the last to be manufactured here. In 1918, the actual anthracene contained in the crude product marketed was about 250,000 pounds, but very little of it was refined so as to make it available for the preparation of dyes, for which purpose it must be at least 80 per cent. pure. The output in 1919 was more than three times as much (813,318 pounds), and a large proportion of it was refined, but it is roughly estimated that had it all been refined there would have been only about one-fifth the amount required for our domestic market, assuming those needs to be in the neighborhood of 4,000,000 pounds pure anthracene per annum.

It is appropriate to point out that this situation is not due to any actual deficiency of anthracene as measured by the sum total present in our tar, nor to any grave technical obstacles to its recovery from a chemical or engineering standpoint, but is directly referable to the fact that its removal by the present method leaves the pitch so hard that it does not find a ready market here, and this makes the anthracene carry all the cost, and the dyes prepared from it would consequently be so expensive that they could not hope to compete with similar products from Germany or England, where hard pitch is readily salable for briquetting coal dust and coke breeze. The problem is one of the most important confronting our dye industry and is being vigorously attacked both by the tar distillers and by the organic chemist, the latter investigating the various methods by which anthraquinone, the most important of the anthracene intermediates, can be made from benzole and a naphthalene derivative (phthalic anhydride). Some success has already crowned efforts of the latter type, and one concern is already manufacturing this anthracene intermediate synthetically on a commercial scale.

When anthracene itself is available, this intermediate is easily produced by oxidation of the former. It is the mother-substance of such valuable classes of dyes as the alizarins (Turkey Red, etc.), indanthrenes, etc., which are of especial service in the dyeing of cotton shirtings, ginghams and calicoes.

The alizarin so prepared is the same as the alizarin obtained in years gone by from madder. This synthesis has already been alluded to, and it was the death knell of the madder industry. In the ten years following this discovery, the output of natural alizarin fell from 500,000 tons per annum to less than 500, and this too in spite of attempted protective legislation on the part of the French Government, for the industry was largely a French one, decreeing that no trousers should be accepted for the French soldiers unless their brilliant red had been produced with natural madder.[12]

METHYL ANTHRACENE AND PHENANTHRENE.

These are relatively unimportant, since they are not yet obtainable in large amounts or at low prices.

Methyl anthracene bears the same relationship to anthracene that toluene does to benzole.

Phenanthrene belongs to a slightly different family, and is of interest also to the pharmaceutical chemist, as it is the mother-substance of the wonderful alkaloid morphine, as well as of certain other alkaloids, but as yet no method has been devised of building them up synthetically from this crude.

CARBOLIC ACID (PHENOL).

The foregoing six crudes belong to the class of compounds known as hydrocarbons, since they are all composed of but two elements, carbon and hydrogen, which are present in varying amounts and united in quite different ways. Carbolic acid, however, contains oxygen as well as carbon and hydrogen and, as its name indicates, possesses acid properties, while the hydrocarbons are neutral and indifferent bodies. Further, it is both a crude and an intermediate; a crude in that it can be separated from coal tar by distillation and purification; an intermediate in that it is prepared synthetically from benzole, as already stated. During the war, when the supply of toluene available was insufficient to provide all the T. N. T. required for bursting charges in shells, mines and torpedoes, recourse was had to picric acid, the raw material for which is carbolic acid. As the amount of carbolic obtained from coal tar was unequal to the task, huge plants were erected by the Government to manufacture it synthetically, the methods most widely employed consisting either in treating the benzole first with sulphuric acid and fusing the product with caustic soda or, when the supply of sulphuric acid also threatened to give out, by chlorinating the benzole first, then nitrating, boiling this product with lime and finally nitrating again. The result of establishing these great plants was an output in 1918 of 106,794,277 pounds of carbolic acid and when the war demand ceased and these plants were closed, a surplus stock of about 35,000,000 pounds was left on the Government's hands. This surplus hanging over the market forced the production for 1919 down to 1,543,659 pounds, and meant a drop in the total value of annual output from $37,270,284 to $155,624.

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[12] In 1919 three firms turned out refined anthracene to an amount recorded above. The output of anthraquinone was 294,260 pounds, valued at $547,787.

Picric acid, by the way, is the basis of the English lyddite, and the French melinite powders. It is a strong yellow dye, and was used for this purpose centuries before its power as an explosive was discovered; in fact, it is the oldest of all artificial organic dyes. In 1711, Woulfe found that by the action of nitric acid upon indigo, a liquid was obtained which dyed silk yellow, and this product was later shown to be picric acid. It was not until 1871 that Sprengel called attention to the fact that picric acid could be detonated, but no application of this observation was made until Turpin, in 1886, proposed its use as a bursting charge for shells.

Chloropicrin, one of the deadly war gases used in considerable amounts by both sides in the recent war, is manufactured by boiling picric acid with bleaching powder in water solution.

The therapeutic properties of carbolic acid are familiar to all of us, and its extensive employment as a general disinfectant and antiseptic.

When carbolic acid is treated first to a dose of caustic soda and then chloroformed, it is transformed into two new substances; one of which is readily changed into a perfume with the odor of the blooming hawthorne and hence sold under the name of Aubepine, from the French name for the hawthorne. The other has a faint but pleasing odor, and occurs in the blossoms of the spirea (ulmaria). By coupling it with the acid found in vinegar (acetic acid), it forms the perfume substance called coumarin, the compound to which the odor of the woodruff and the sweet clover are due, and which is the odoriferous and gustiferous principle of the tonka beans. These latter are often mixed with vanilla beans, because of their vanilla-like flavor and aroma, in the preparation of the natural vanilla extracts, as they give to the extract a rather pleasanter bouquet. As the organic chemist can synthesize the important component of vanilla beans by starting with wood tar, it is entirely within his power to fabricate a high-grade vanilla extract of fine bouquet, in which the alcohol has been made from limestone and coke, or possibly from sawdust, the vanilla from wood tar and the bouquet from coal tar. Coumarin is the basis also of most " new-mown hay " perfumes.

If, instead of chloroforming our carbolic acid after its caustic soda treatment, we bake it in presence of the gas which bubbles up in our soda water, the product is the familiar salicylic acid,[13] so extensively employed as a remedy, either in the form of the acid itself, its salts, or such derivatives as aspirin, salol, salophen, and the like, in cases of rheumatism, grippe, headaches and fevers, and also made use of as a food preservative and for the manufacture of many dyes. I have already shown you how we can combine this rheumatism acid with wood alcohol and produce the synthetic oil of wintergreen.

But let us vary once more the method of attack, and subject our carbolic acid to the action of dilute nitric acid. The result will again be two distinct and new products; one of which yields dyes and other derivatives of commercial value, while from the other one, the valuable drug phenacetin is manufactured.

Under the influence of a somewhat stronger nitric acid, carbolic acid yields an intermediate which may be converted on the one hand into picric acid, or on the other into Sulphur Black, a dye which is consumed in the United States in larger amounts than any other, over 14,500,000 pounds having been produced here in 1919 by 13 different manufacturers, and some of their brands being admittedly superior to the finest products imported from Germany prior to the war. With a still stronger nitric acid, assisted by some concentrated sulphuric acid, carbolic passes into picric acid, which has been discussed above.

The synthetic resins of the bakelite, condensite and redmanol type, are prepared from carbolic acid (or cresol) and formaldehyde (or closely related compounds). These synthetic resins have found a wide sphere of usefulness as substitutes for hard rubber, since they can be filled, molded, machined, etc., and have a high dielectric constant. Synthetic tannins of the neradol class are prepared from these same initial materials.

The mild laxative, phenolphthalein, is likewise a carbolic derivative.

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[13] In 1919 the U. S. production of technical salicylic acid was 3,467,055 pounds, valued at $1,009,462, and of the U. S. P. grade, 2,619,726 pounds, worth $918,832.

CRESYLIC ACID (CRESOL).

Cresol, or cresylic acid, is another case of triplets, much like the xylenes, with the same first names, and bearing a relationship to carbolic acid similar to that of the xylenes to toluene.

These cresols are present in the creosote or dead oil from coal tar, the main use of which is for the preservation of wood (telegraph poles, fence posts, railroad ties, paving blocks, etc.), although some is employed also in the preparation of sheep dips, of lysol and of other emulsifiable disinfectants.

It is not an easy task to separate the three cresols from the crude material and obtain them pure, but when they are so isolated they are found to have much the same properties as carbolic acid and to be serviceable for similar purposes. Their non-availability is reflected in their limited use for synthetic purposes.

Carbolic and cresylic make up the bulk of what are termed the tar acids. The chief source is gas tar, for the tar from coke ovens contains but small amounts.[14]

CARBAZOLE.

This crude differs radically from the foregoing in that it is composed of carbon, hydrogen and nitrogen.

It occurs in coal tar associated with anthracene and is separated with it. An increased demand for carbazole would thus encourage manufacturers to refine their anthracene. In 1919, but one firm reported the commercial production of carbazole, although it is the raw material for a very valuable dye called Hydrone Blue.[15]

In what perhaps has seemed to you a rather long drawn out cataloguing of coal tar products, I would remind you that we have considered but five crudes in any detail, and even in these enumerated but a few of the many thousands of compounds to which they give rise, while over 150 other separate and distinct chemical individuals have been isolated from coal tar, each of which is the starting point of other long series of descendants; and coal tar is not the only source from which the dye industry derives its initial materials. The Coal Tar grove is, therefore, both flourishing and extensive. The synthetic dye industry is primarily and chiefly responsible for its wonderful development and rich fruitage, and without the fostering care of that industry it will speedily languish and decay.

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[14] In 1919 our production of creosote oil was 43,434,059 gallons, valued at $4,264,594; and we imported 11,268,359 gallons additional, at a cost of $1,374,217. Purified cresol to the amount of 6,435,650 pounds was imported, at an expense of $557,214.

In 1918 o-cresol was manufactured commercially in this country, but no meta or para has been reported.

[15] During the 1920 fiscal year (July 1st to June 30th), we imported 21,593 pounds Hydrone Blue, at an invoice value of $8375.

INFLUENCE UPON ADVANCEMENT OF CHEMISTRY.

The influence of the synthetic dye industry upon the advancement of the science of chemistry has been deep and far-reaching. For the solution of many of the problems arising in the plant, experts in all branches of chemistry must be enlisted, and the results of this concentrated and intensive investigation have led not only to the solution of the particular problem immediately in hand, but of many collateral problems as well, inorganic as well as organic, and not infrequently to the uncovering of new laws of fundamental significance to the entire science.

Great industrial research laboratories have been established and organized by the manufacturers, manned by able investigators and, in Germany for example, the university laboratories have often been called into active coöperation, thus adding the knowledge and experience of the university professor to that of the technical staffs of the plants on the one hand and, on the other, vitalizing the university teaching by bringing the teacher into actual personal contact with the applications of his lectures and keeping his information more nearly up to date. It is a pleasure to record that this coöperation has also taken the form of endowments in several instances, providing much needed financial assistance for our educational institutions, and giving to deserving students an opportunity otherwise unattainable of gaining advanced training and thus becoming more useful citizens.

For the highly trained synthetic organic chemist, the dye industry with its collateral and related industries makes the greatest demand. As the manufacture of explosives and of chemical warfare munitions is likewise mainly dependent upon men with similar education and experience, and much of the equipment and many of the operations are alike in all three lines of activity, it will be readily understood why a modern synthetic dye plant is referred to as " a potential arsenal." Germany's great dye plants were converted almost over night into real arsenals for the manufacture of munitions.

Badly handicapped as we were in the matter of dye plants when we entered the war, our most serious deficiency was the lack of a sufficient number of skilled organic chemists to man new plants when these were ready. Under the stress of war conditions, a factory may be erected and equipped in six months, but it takes six years' education after high school to fit a man to begin learning the practical operations involved in large-scale production, and many months of such experience before he can really handle his job efficiently. It may be that a million men " will spring to arms over night," but the crop of chemists grows more slowly.

Following the armistice, large numbers of young men entered our universities filled with enthusiasm over the prospects of developing in our country a great dye industry, and eager to prepare themselves for a worthy part in that expected development. The attitude of Congress, in holding up for nearly two years the legislation necessary to protect and encourage this business, has chilled the enthusiasm of these students, and many are either in serious doubt as to the wisdom of embarking upon such a career, or have already switched to something else. A continuance of this attitude on the part of the Congress will result in an immediate and considerable reduction in the number of young men selecting organic chemistry as a profession, and should our country be forced into war in the near future, she will once more be wholly unprepared through absence of the experts necessary to increase her output of munitions, and the lack of officers for the industrial army is fully as serious as for the military army.

Of the 214 concerns engaged in the manufacture of dyes or intermediates in the calendar year, 1919, 65 maintained separate research laboratories for the investigation of problems arising in the works and for the discovery of new substances or improved processes. The amount of money spent on these laboratories that year for salaries, apparatus and supplies, deducting the salable products turned out by them, but without figuring any overhead or all the cost of translating test-tube results into successful large-scale operation, was $4,274,247.

WHAT WOULD THE LOSS OF THIS INDUSTRY MEAN TO US?

Let us understand fully what the curtailment or abandonment of this industry is likely to involve, for it is not so much the amount of money involved, although that is considerable, as it is the bearing upon our life as a nation that counts. Its immediate consequences, some of which are making their appearance even now, may be briefly recapitulated as follows:

1. Thousands of unskilled laborers thrown out of employment.

2. Large numbers of specially trained technical experts forced to seek other means of livelihood, and the economic loss involved in scrapping the experience gained in the dye industry.

3. Abandonment by the manufacturers of all plans for development and expansion, and the closing of plants now in operation.

4. Fewer students for the courses in chemistry at our educational institutions.

5. Termination or reduction of research work, both in the laboratories of the industry and in coöperative investigations with educational institutions, with all that this implies in retardation of the development of our science at a time when the world is looking to us to take the leadership.

6. Inability of teachers of applied organic chemistry to give their students up-to-date information in the field of synthetic dyes, through loss of personal contact with the manufacturer, and an inevitable resulting dependence upon the ancient history of the average text-book of industrial chemistry.

7. Subjugation of our great textile industry, and of other industries using dyes or dye intermediates, by foreign manufacturers, and in the event of our being cut off from such supplies by another war, once again to be face to face with a famine, not only in the dyes needed for our flags, uniforms, and other articles, and the bacteriological stains for the diagnosis of disease, but in many indispensable drugs and in compounds of serious concern to the manufacturers of photographic chemicals, food preservatives, explosives, toxic gases and other war munitions, paints, inks, perfumes and flavoring principles, artificial resins, plastics, tannins, and accelerators for rubber vulcanization; the distilling of coal tar and the recovery of by-products from the coking of coal will also suffer from the loss of this market for their products.

8. Should we be one of the belligerents, there will be but few dye plants available for conversion to munition manufacturing (be it explosives, toxic gases, smokes, incendiaries, or what not), and no reserve of trained men to take charge of such operations. It is trite, but true, that modern military power is dependent upon industrial organization and efficiency.

9. Domination of our trade in dyes and dye intermediates, by

Germany for example, is quite certain to lead to the control of others of our industries as well, until the penetration of our industrial fibre will resemble that of the chestnut tree by the deadly fungus which has so nearly obliterated these beautiful trees from our groves.

10. The world markets open to other nations will be inaccessible to us.

It is no exaggeration to say that the life of the state, as of the individual, some day may be decided by the existence or non-existence here of a well-developed, expanding and progressive synthetic dye industry, and if this hasty and very imperfect presentation of the subject has helped to give you any better appreciation of its significance to all of us, I shall feel well repaid for the time spent in putting together these rather rambling remarks.

As chemical warfare was responsible for nearly a third of all our casualties in the war, and as this proportion is quite certain to be higher in future conflicts, it is idle to talk about disarmament without including the munition plants represented by Germany's great dye industry and nitrogen-fixation units. Because of the rôle which these play in the economic life of the nation at peace, they cannot be destroyed without destroying Germany as well. Where disarmament is impossible, there is but one answer—counterbalancing armament. Hence, the one sane and practicable disarmament which we can really accomplish is an offsetting equivalent or superior development of our own dye and air-nitrogen industries. It is the most effective guarantee of peace, and in the long run much the cheapest form of insurance.

The important question is "Do you want the synthetic dye industry to remain and develop in this country, or not?" If you do not, or are wholly indifferent, take no action whatever. The German propaganda and its friends will do the rest for you. But if you are convinced that this industry is linked in so vital and intimate a manner with the welfare of our citizens and the safety of our state that it is essential to the maintenance of our proud position among the nations of the world, you will do what you can to see to it that such legislation is promptly enacted as will provide adequate protection while the industry is still adolescent and vulnerable, and will immediately wire your senators and representatives in the Congress urging such action upon them, for "Where there is no vision, the people perish."

SOME OPERATING CHARACTERISTICS OF ELECTRON TUBES.*

BY

W. C. WHITE, E.E.

Research Laboratory, General Electric Company, Schenectady, N. Y.

The three-element vacuum tube is becoming a fairly common tool to the physicist, electrical engineer and experimenter, and the literature on the subject has grown rapidly, so that at the present time it is really voluminous.

Its theory of operation is quite widely known and is found in most modern textbooks on physics and radio communication. Radio literature is usually generously sprinkled with vacuum-tube circuit diagrams.

It is not the purpose of this paper to take up any of the fundamental theories of operation of the tube or its circuits, but to furnish information and give help to those who professionally, or for pleasure, experiment with these devices.

It is also not the intention to attempt to cover the field of tube operation, but merely to call attention to certain phases of the subject not widely known or appreciated.

It is a rather usual occurrence to those working with vacuum tubes in an experimental way to encounter unlooked-for difficulties and obtain unexpected results.

A number of these more unusual effects will be discussed; first those of a general nature, next those occurring when the tube is used as an oscillator, and finally a few when the tube is used for a number of other purposes.

A tungsten filament type of tube is assumed in the paragraphs to follow, and most of the discussion relates to power tubes.

Certain properties of a tungsten filament as an electron emitting source will first be mentioned, for although these are simple and probably well known, they will bear repetition because of their importance in obtaining satisfactory results with such a type of tube.

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* Presented at the Stated Meeting of the Institute held Wednesday, December 15, 1920.

The electron emission and life of a filament are quite sensitive to changes of filament current. A 1 per cent. change in filament current causes about a 25 per cent. change in life and approximately a 10 per cent. change in total electron emission. An increasing filament current decreases the life and increases the emission.

Owing to the fact that, like most other metals, tungsten has a positive temperature coefficient of resistance, a certain percentage change of current gives a correspondingly greater change of voltage. Numerically this amounts to a 1¾ per cent. change of voltage for a 1 per cent. change of current. Therefore life and electron emission from a tungsten filament are more subject to filament current change than voltage change of the filament.

Although in the past it has usually been the custom to operate the tungsten filaments of vacuum tubes at an approximately constant current by means of an ammeter, operation at constant voltage is to be recommended as giving a much longer life to the filament in about the ratio of three to one.

In operating tungsten filaments in vacuum tubes, observance of the three following rules will greatly increase the useful life of the tube:

(1) The most favorable adjustment of the set, of which the tube is a part, is the one which gives the desired result with the lowest value of plate current.

(2) The filament current or temperature should not be materially raised to give a slightly increased output or signal which is not vitally necessary.

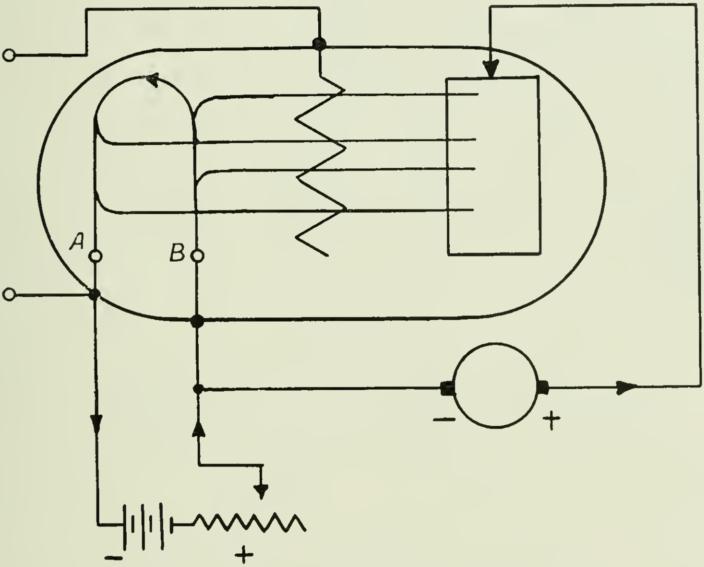
(3) Do not, for any length of time, exceed the maximum filament rating, and in all cases reduce the filament temperature to as low a value as is consistent with satisfactory operation of the apparatus.

Most tubes are designed for operation in one or two designated positions: that is, vertically or horizontally, with a certain side or end up. It is advisable to observe this feature because a hot tungsten filament has a tendency to very slowly sag, and if this is not prevented or compensated by operation in a certain designated position, there is liable to be changes in the electrical constants of the tube, caused by changes in distance between the electrodes.

If for some reason the vacuum in a tube becomes faulty, it is usually noted by the characteristic glow due to ionization of the gases present. If gases evolved from the metal parts or glass, due usually to the heat from an overload, are the cause of this glow, it will be blue in color; whereas, if it is due to leakage air, it will appear purple or pink.

Occasionally a tube will be met with which, when the filament is energized, shows a sort of yellowish-white smoke in the interior near the filament or it fails to come up to normal brilliancy at rated ampères and a dark-blue powder forms on the plate and grid. Both these effects are due to considerable amounts of leakage air, but formed under different conditions.

FIG. 1.

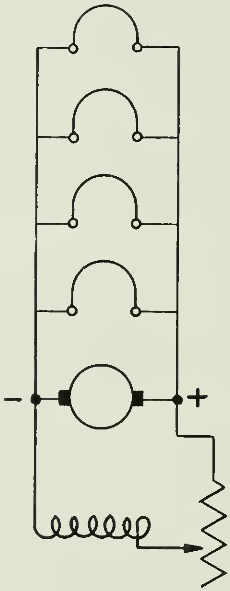


The smoke or powder formed is an oxide of tungsten which exists in several forms and varies in color from a very light yellow to a very dark blue, depending upon the conditions at the time of its formation.

One limit to the possible output of a tube as an oscillator is the amount of energy that can be dissipated safely in the form of heat. If it is attempted to dissipate too much energy, the glass and electrodes will be liable to evolve gas which reduces the vacuum. If the tube is enclosed in a small unventilated space, normal operation may overheat the glass of the bulb and cause it to evolve gas. This is most likely to occur where a number of tubes are operated in parallel, thus causing a considerable energy dissipation in a small area.

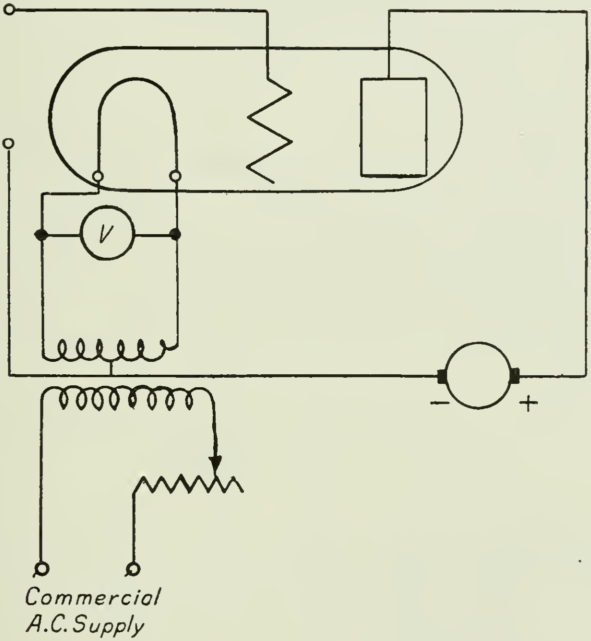
When the filament of a power tube is operated from a direct current source through a regulating resistance, the plate current causes an inequality in the filament current. This action is represented in Fig. 1. The electron emission occurs along the length of the filament and therefore one end of the filament will carry more total current than the other end; this causes one end of the filament to be the hotter, which for the same amount of emission will shorten the life. The relative resistance values of the regulating rheostat and the filament, and also the location of the point of connection between the filament and plate circuits, determines the amount and direction of this effect. As shown in Fig. 1, the plate current causes the filament temperature to decrease at the positive filament terminal. This is the safest and best mode of connection.

Fig. 2.



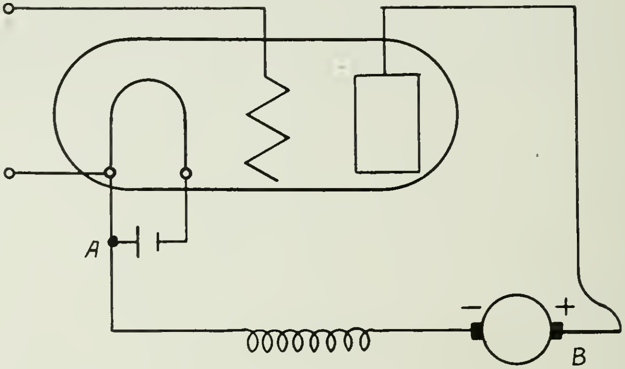
If, however, the filament is operated from a few cells of storage battery or directly from a low-voltage direct-current generator so that the resistance in series with the filament is small, it is immaterial whether the return from the plate circuit is made to the positive or negative terminal of the filament; the heating current in the negative side of the filament is increased by the same amount. A considerable resistance in series with the filament is essential to any alteration in the distribution of the flow of plate current through the filament circuit as a safety precaution. As the plate current is usually in the neighborhood of 2 per cent. to 7 per cent. of the filament current, and as a 3 per cent. increase of filament current halves the life of a tungsten filament, the importance of this effect is evident.

FIG. 3.



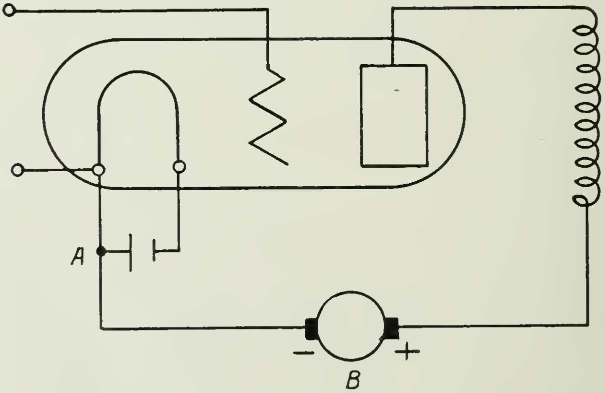
If a low-voltage direct-current generator is used for filament lighting, it is usually connected in circuit as shown in Fig. 2, the filaments being directly connected to the armature leads, the adjustment of filament temperature being made by a rheostat in the field circuit of the generator. With such an arrangement difficulty may be experienced with the generator not building up if the filaments are left in circuit. This is owing to the fact that the cold resistance of a tungsten filament is very low, only one-thirteenth to one-sixteenth of its normal operating resistance. Therefore, if a small low-voltage direct-current generator is used at full load to supply tungsten filaments, the cold resistance of the filaments may be so low that it acts as practically a short circuit on the armature and prevents the generator from building up.

Fig. 4*a*.



On power tubes it is preferable to use alternating current for filament excitation. The chief reason for using *A.C.* is that it obviates the unbalanced condition of a *D.C.* filament current, as described in a previous paragraph. It is also more practical to generate and distribute the low-voltage high-current energy for filament operation by means of *A.C.*

Fig. 4*b*.



In using *A.C.* for filament excitation the filament terminals should be connected directly to the transformer low-voltage terminals, the regulating resistance being placed on the power side. Also the return of the grid and plate circuit should be made to a centre tap of the coil supplying the filament. This mode of connection assures minimum disturbance in the plate and grid circuits from the frequency of the filament source. Both these points are shown in Fig. 3.

Some points in connection with the use of tubes as oscillators will next be taken up.

In the various diagrams of connections which are shown in this paper, each one is simplified so as to more clearly show the point under discussion. For this reason many diagrams for clearness or simplicity omit features which in another paragraph are shown to be advisable.

FIG. 5*a*.

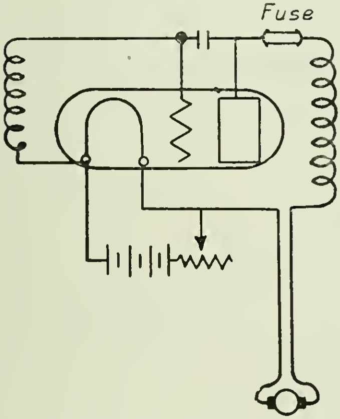
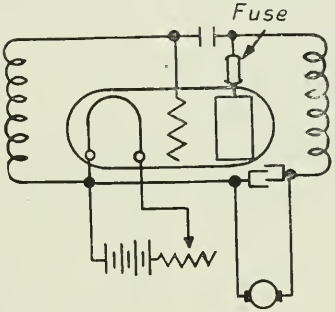


FIG. 5*b*.



In all tube oscillator circuits there is an inductance in the plate circuit across which the high-frequency voltage is set up. Care should be taken that this inductance is not placed between the filament energy source and the plate energy source, as shown in Fig. 4*a*. Both of these sources have usually a large capacity or a certain resistance to ground, so that a circulating current will flow through the coil and through each source to ground. For the type of circuit shown the correct arrangement is shown in Fig. 4*b*. The importance of having the circuit correct in this respect is greater the greater the power and the higher the voltage used.

In arranging an oscillating circuit to deliver high-frequency energy, it is important to reduce to a minimum the losses in the high-frequency circuits. Not only should the wires used be of low resistance and the condensers have low losses, but it is best to trace through the circuits carrying high-frequency currents to be sure that the resistance is a minimum.

Three common errors in this respect are shown in Fig. 5*a* which represents a capacity coupled oscillator circuit. In this diagram the high-frequency current of the oscillating circuit must pass through a resistance path comprising the filament in parallel with its resistance and battery source. Also it must pass through a fuse in the plate circuit and through the plate voltage source. In Fig. 5*b* the same circuit is shown with these three errors corrected, the first, by changing the wiring so that the return of the grid and plate circuits is brought back to the same filament terminal; the second, by change of the fuse position, and the third, by shunting the plate circuit generator with a by-pass condenser.

Fig. 6*a*.

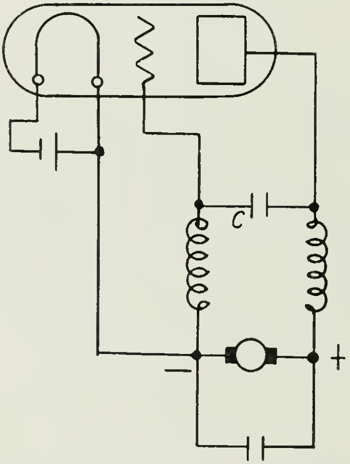
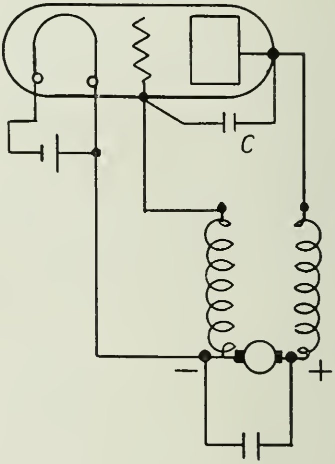


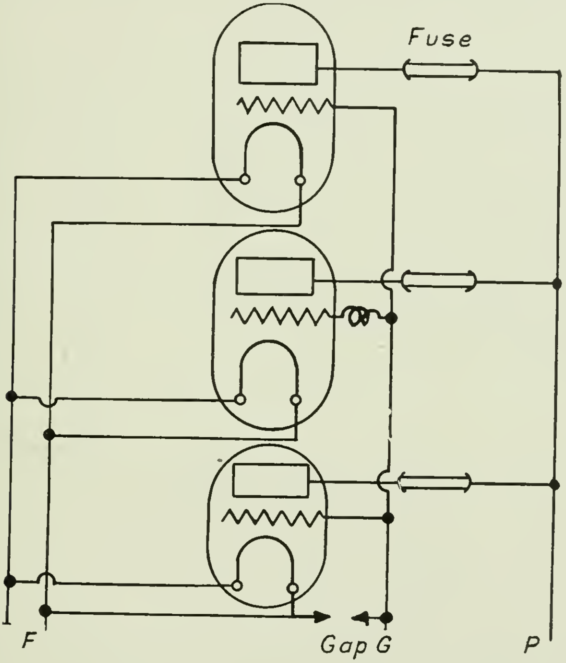
Fig. 6*b*.



For miscellaneous laboratory work the capacity coupled type of circuit is a very convenient one to set up and operate, usually giving little trouble. However, if the circuit happens to be set up in a certain peculiar way, very puzzling results and failure to operate may sometimes occur, particularly if a tube of low impedance is used or several tubes in parallel.

This arrangement is shown in Fig. 6*a*. If, as shown in this diagram, the leads from the coupling condenser *C* are connected to the plate and grid coil terminals rather than to the corresponding tube terminals, as shown in Fig. 6*b*, very high-frequency oscillations may occur, a second capacity coupled circuit being formed, the capacity between the electrodes acting as the coupling condenser and the leads between the grid and plate coils and the corresponding tube terminals acting as the grid and plate inductances. This condition is accentuated by having these leads long and the leads to the coupling capacity short.

FIG. 7.

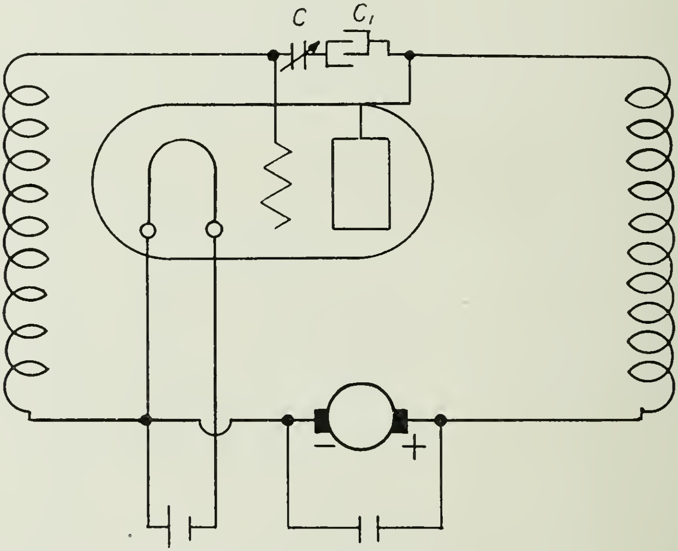


This unexpected production of ultra high-frequency oscillations is often a very troublesome problem in high-power tube apparatus when a considerable number of tubes are operated in parallel. The low impedance of the tubes in parallel accentuates the effect. One expedient which often aids in overcoming this difficulty is the insertion of a very small inductance (a few microhenries) in one or more of the grid leads close to a tube grid terminal.

This coil is shown in Fig. 7. This figure also shows fuses in the plate circuit of each individual tube, a very desirable feature on high-power high-voltage tubes. This fuse should blow at two to four times the rated plate current of the tube.

This Fig. 7 also shows another desirable feature for high-voltage power-tube circuits. In experimental work with oscillating circuits unusual conditions may occur which will cause transient voltages to be set up between the grid and filament which will reach peak values many times higher than that set up in normal operation. It is impractical to design and construct a tube and its base to stand up under this very abnormal voltage, which only occasionally occurs, due to incorrect adjustment.

FIG. 8.

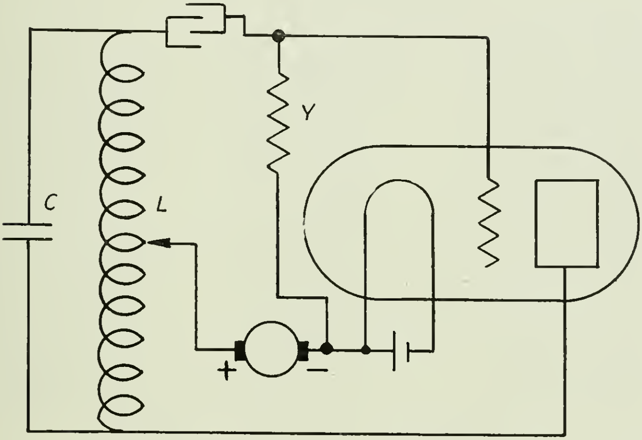


A safety spark gap should therefore be provided between the grid and filament terminals at or near the tube socket or mounting. This gap should be adjusted to between one-thirty-second and one-quarter inch, depending upon the plate voltage employed and the number and type of tubes used. This precaution should be taken on any tube or group of tubes delivering over 50 watts of alternating current energy or operating at a plate potential above 2000 volts.

In one of the simplest and most frequently used forms of capacity coupled circuit there is a precaution that should be observed.

This is illustrated in Fig. 8. It will be noted that the coupling capacity *C* has one of its terminals connected through the grid coil to the negative terminal of the high-voltage plate source, while the other side of this capacity is connected through the plate coil to the positive terminal of the high-voltage source. Very often this capacity *C* is a variable air or oil dielectric condenser, and its breakdown due to high frequency high voltage will therefore short-circuit the generator on *D.C.* source. The resultant arcing inside the condenser may also burn the plates badly.

FIG. 9.

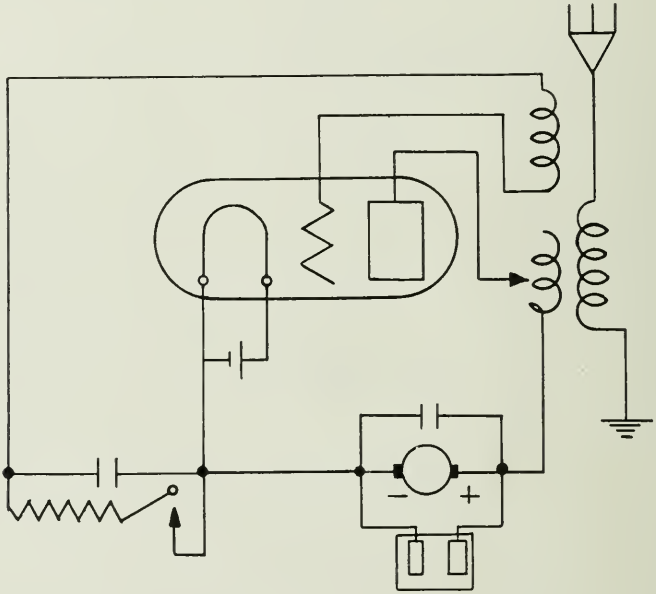


This possibility may be prevented by the use of a second capacity C_1, which should be large in capacity in comparison with *C*. The condenser C_1, if it is at least one hundred times the value of *C*, need not be a low loss condenser. It is necessary of course that the condenser C_1 safely stand the voltage of the *D.C.* source.

In a typical form of oscillating circuit, as shown in Fig. 9, the frequency of oscillations is principally determined by the value of the capacity *C* and inductance *L*.

As far as the natural frequency of oscillation is concerned, it will remain constant as long as the product of *L* and *C* is constant. However, it will be found that the type of circuit shown in Fig. 9 will only oscillate at a given frequency in a satisfactory manner when the capacity C is under a certain limiting value. This is explained by the fact that certain values of high-frequency voltage are necessary on the grid and plate. If the capacity C is very large the tube will not supply sufficient energy to pass enough current through C to set up across it the necessary grid and plate high-frequency voltage. The lower the value of resistance and the lower the losses in the oscillating circuit the larger the value of C that may be used and still maintain oscillations.

FIG. 10.

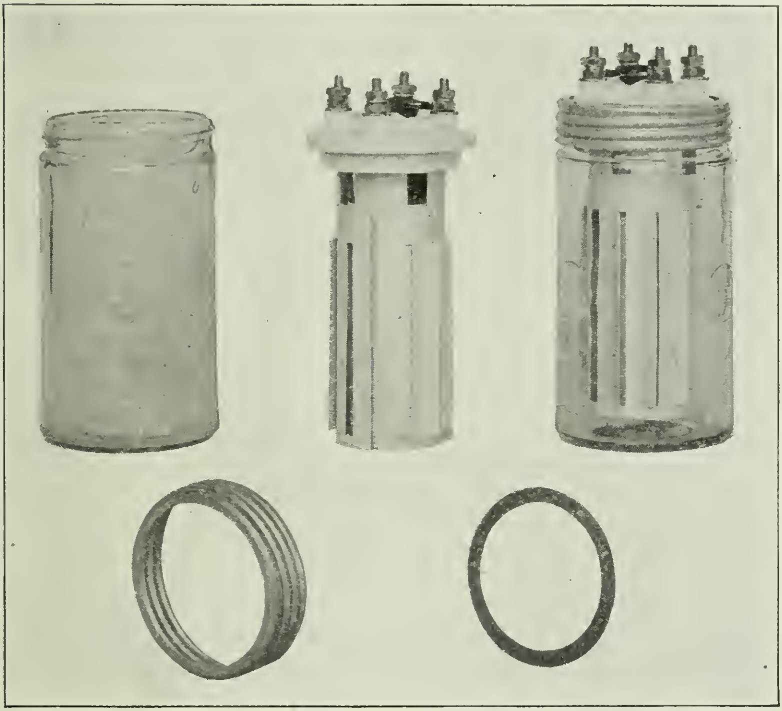


For the type of circuit shown in Fig. 9, the limiting value of C, for the usual types of small tubes running at reasonable values of plate voltage, is in the neighborhood of a maximum of .001 microfarad for a frequency of one million cycles (300 metre wavelength). This is necessarily a very approximate figure because of the many factors which are involved, but it at least gives the experimenter an idea of what not to use.

In the use of high-voltage direct-current generators operated singly or in series, it has been found that when they are employed for supplying energy for tube-plate circuits a considerable strain is imposed on the insulation of the armatures. This is particularly accentuated when the tubes are used for radio telegraphy and telephony where the load fluctuates rapidly or is switched off and on suddenly. For the usual type of circuits, one of which is shown in Fig. 10, the negative side of the generator is practically at ground potential.

This strain which is imposed on the machine is in the form of a voltage surge which momentarily raises the generator voltage several fold. One terminal being grounded, the strain occurs on the insulation between the frame or armature core and an armature conductor which at the instant is near the positive terminal or brush.

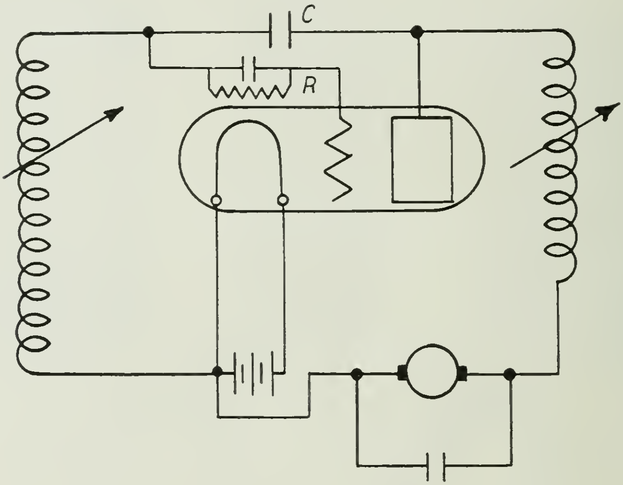
FIG. 11.



A condenser shunted across the generator terminals, described in a previous paragraph, also acts as a sufficient protection against these voltage strains in the case of very small machines. In the case of generators, singly or in series, for voltages above 500 and power outputs above 50 watts, some sort of protective device to safely limit and discharge this voltage should be used. For this service aluminum cell lightning arresters are very suitable. They should be connected across the generator terminals. In Fig. 10 one protective cell is shown in circuit.

These cells consist of a pair of oxidized aluminum plates immersed in an electrolyte. Many different electrolytes are used to meet special requirements, but for experimental purposes covering a short period of time a saturated solution of borax is satisfactory. These cells are connected in series, and when the oxide film is properly formed one cell should be used for each 300 volts of rated generator voltage. These cells involve the same general principles as the familiar type of electrolytic rectifier.

Fig. 12.



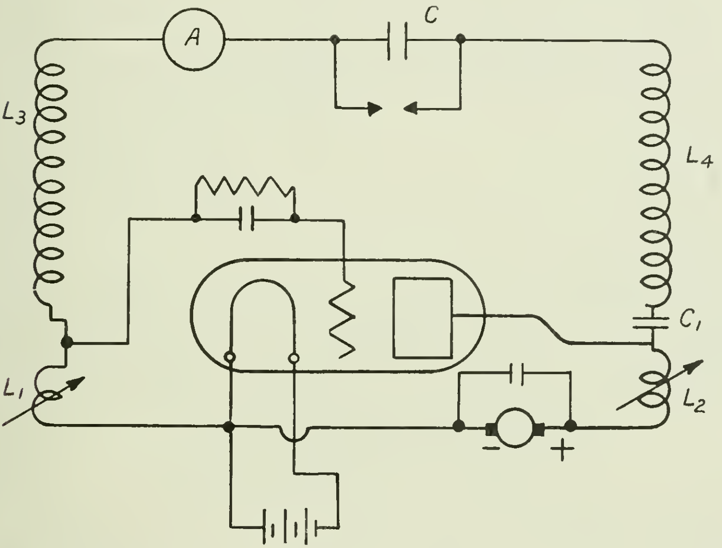
These cells, owing to the thin oxide film acting as a dielectric, have considerable electrostatic capacity between electrodes, which is an added advantage in their use as protective devices on generators supplying oscillating vacuum tubes.

A typical form of aluminum cell protective unit is shown in Fig. 11.

In certain experiments it is often desired to keep the frequency variation of a tube acting as a high-frequency oscillator as small as possible. This is particularly desirable in the calibration of wave-meters and in measurement work. The variation of frequency due to voltage variations of the power sources can be greatly minimized by using a very high value of grid leak resistance *R*, as shown in Fig. 12. This applies to practically all types of oscillating circuits.

It is often desired to obtain high-voltage high-frequency energy to test dielectrics and measure dielectric losses. Fig. 13 shows a type of circuit very suitable for using an oscillating tube for this purpose. The frequency of oscillation is largely determined by the period of the simple series circuit comprising L_1, L_2, L_3, L_4, and C. The condenser C_1 is merely for safety, as explained in a previous paragraph, and is large in comparison with C. Maximum output is obtained by variation of L_1 and L_2. The voltage obtained may be computed by measuring the frequency with a wave-meter and reading the current at *A*, passing through the condenser C of known capacity value. A spark gap across C may also be used to check the value of voltage obtained.

FIG. 13.



For high voltages the capacity C should be small and the inductance in circuit large. It is also important to have the losses low in the inductances and capacity.

In most power tubes the higher the plate voltage that can be used the greater the output. Tubes may fail to stand up under an increased voltage for many reasons, but there is one factor in connection with this limitation that is usually overlooked. This factor is electrolysis of the glass. In most of the types of small-power tubes all the lead-in wires are usually carried through a common stem and seal. When this is the case the plate voltage that may be used is limited by electrolytic action in the glass of this seal between the plate and grid leads. Hot glass is an electrolytic conductor; that is, the metallic elements in the glass appear at the negative pole. This electrolysis in the course of time, if continued, will ruin the seal, making it leak air, and sometimes

Fig. 14a.

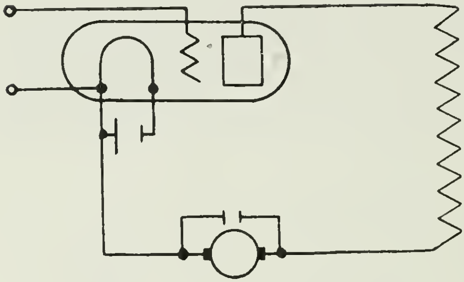


Fig. 14b.

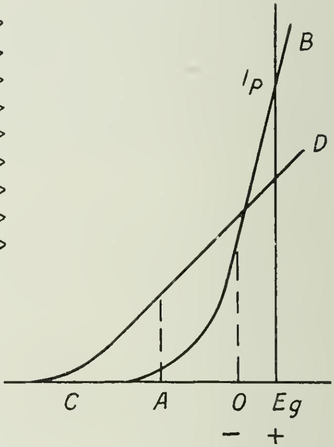
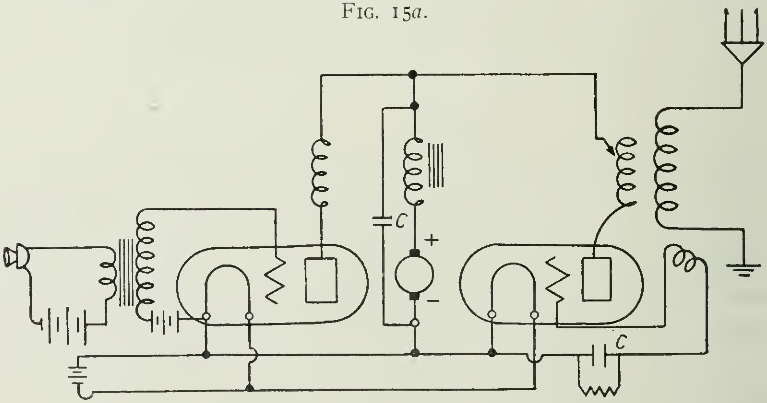


Fig. 15a.

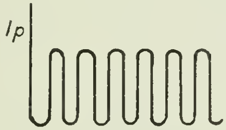


even cracking it. An early indication of this electrolysis which appears long before leakage occurs is a blackening of the grid leads in the glass of the seal near the vacuum end. This action takes place at the grid lead, because this is usually the most negative one when the tube is oscillating.

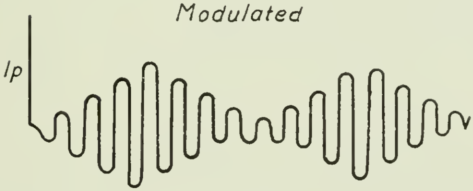
Therefore, if tubes of this type are operated considerably above their rated plate voltage the life is liable to be terminated by leakage of air into the bulb through the seal rather than filament burnout.

FIG. 15*b*.

Not modulated



Modulated



In the various circuits described the source of *D.C.* potential for the plate has been shown in series with the plate inductance. The shunt feed method of connection is just as satisfactory, but is sometimes not quite so convenient for the experimenter with limited apparatus.

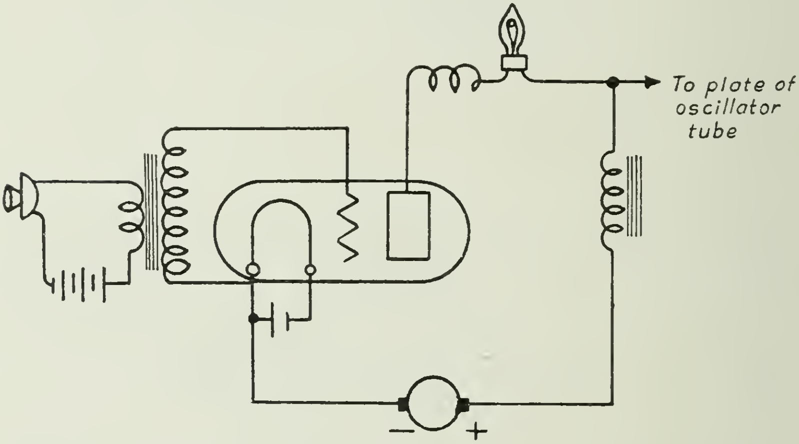
Also the various circuit diagrams in this paper have for the most part shown, for the sake of simplicity, a battery as a filament source and a *D.C.* generator as a plate source. The filament battery may of course be replaced by a generator or transformer and the plate generator by a battery or a rectifier system for producing *D.C.* from *A.C.* at commercial frequencies.

There are a few points of interest that arise when a tube is used as an amplifier for alternating currents of appreciable energy (several watts at least), and when it is used as a voice current amplifier and modulator in radio-telephony.

A very common form of graphical plot employed to show one of the electrical characteristics of a three-element tube is given in Fig. 14*b*. The curve *A-B* illustrates the well-known relation between grid voltage and plate current. This curve assumes a constant plate voltage. However, in many amplifying circuits a resistance, as in Fig. 14*a*, is included in the plate circuit.

When an alternating E.M.F. is connected between filament and grid a corresponding variation in plate current occurs. Therefore an alternating voltage is set up across the resistance in the plate circuit and the voltage of the plate is no longer constant, being higher than normal voltage while the resistance is discharging and lower when it is charging. For this reason the grid voltage and plate current will not follow the curve *A-B*. They will, however, follow a curve of the type *C-D*, because at the low-plate current the plate voltage is higher than normal and therefore a higher negative voltage is required to bring the plate current to zero, while at the higher plate-current end the actual plate voltage is lower and so the plate current is lower.

Fig. 16.



In most amplifying circuits it is usually desired to keep the grid negative during practically the entire cycle of operation, and therefore the grid is made normally negative by a so-called biasing potential. It is also usually desirable to make this normal negative potential of a value equal to half the grid voltage required to bring the plate current to zero. This value of normal negative grid voltage should be computed from the curve *C-D* rather than the static curve *A-B*. In other words, the best value of negative biasing grid voltage should reduce the plate current to much less than half the value obtained at zero volts on the grid. A negative voltage that reduces it to about one-quarter value is approximately the best.

The foregoing, of course, does not apply to receiving amplifiers or cases where the amount of plate-current fluctuation is small.

The most usual method of modulation employed for vacuum-tube radio-telephone transmitters is shown in Fig. 15. In this arrangement the output of the oscillator tube is varied above and below its normal amount by variations in plate voltage set up by the amplified microphone voltages. Therefore the peak of plate current in the modulated oscillator tube is considerably higher than in a straight oscillator circuit. More electron emission is therefore required for the modulated tube than for a simple oscillator tube. Very often poor articulation in a radio-telephone transmitter is due to insufficient electron emission in the oscillator tube.

In a radio-telephone transmitter correct wave-length and normal antenna current are not, as in telegraphy, indications that the set is functioning properly. Neither of these factors give any information as to the degree of modulation. The amount of modulation is most satisfactorily obtained by means of an oscilliograph, but this is seldom available for use when and where desired.

A simple device to indicate modulation is a miniature tungsten filament lamp in the plate circuit of the modulator tube. This should be chosen of such a rating or so shunted that normally it burns at a dull red. When the microphone is spoken into, it should flash up and the degree of this brightening soon becomes a very good indication to the operator as to whether the modulation is normal or not. This arrangement is shown in Fig. 16.

There are so many things that may prevent a radio-telephone transmitter from properly functioning while showing full radiation current that an indicator, as described above, is very useful.

Studies with the Ionization Gauge. S. DUSHMAN and C. G. FOUND. (*Phys. Rev.*, January, 1921.)—Not many years ago the McLeod gauge for the measurement of gas pressures marked an advance in the technic of the physical laboratory, but the recent improvements in the production of high vacua have made imperative a gauge capable of measuring pressures much less than those within the range of the McLeod instrument. Both in this country and in Japan gauges have been devised in which the pressure of the gas present is inferred from the positive ionization produced in it by a stream of electrons.

In the instrument designed by the present investigators there are two co-axial tungsten filaments surrounded by a molybdenum cylinder. Great care is taken to remove all water vapor and to get rid of gases occluded in the cylinder and in the leads. After this had been accomplished argon was admitted to the space surrounding the spirals. The inner was the cathode, the outer one the anode, and the cylinder was kept at a potential lower than the most negative part of the cathode. The electron discharge from the cathode travels toward the anode and on its way ionizes some of the molecules of the gas in its path. The positive ions thus produced are drawn over to the negatively charged cylinder. The larger the number of gas molecules in the way of the electrons the larger the number of positive ions resulting and the greater the positive charge conveyed to the cylinder. By comparing the new type of gauge with the McLeod form for the same gas pressures it is found that the positive ionization current is directly as the gas pressure up to a certain pressure which varies with the electron current employed. This justifies the employment of the ionization current as a measure of the pressure. Pressures as low as .0001 bars have been measured, corresponding to one ten-millionth ampere of positive ionization current.

When the outer spiral is the cathode and the inner one the collector of positive ions, while the cylinder serves as anode, the instrument is applicable to a wide range of pressures.

G. F. S.

Radiotelephony on the Farm. (*Popular Sci. M.*, November, 1920, p. 65.)—Michigan farmers who live far away from civilization will soon be able to know what is happening in the big city at any time of the day. The Michigan Agricultural College has planned a system of wireless telephones to be installed on all the large far-distant farms.

The Michigan farmer will be able to know at all times the market prices of his products. He will receive weather forecasts and listen to lectures or music when he has nothing else to do. His equipment provides for receiving messages, but not for sending them.

THE ECONOMIC ASPECTS OF RAILWAY ELECTRIFICATION.*

BY

A. H. ARMSTRONG, M.E.

Chairman, Electrification Committee, General Electric Company, Schenectady, N. Y.

An industry valued at some nineteen billions of dollars cannot be ruthlessly tampered with and escape serious economic disturbance, especially when it is closely interwoven with our national prosperity. The story of our railway development is part of the written history of the country. It is, therefore, a matter of grave national concern to properly diagnose the true nature of the ailment affecting our transportation system and prescribe the treatment of greatest promise for its future recovery.

To the great main lines binding East and West, North and South have been added branches reaching into new country and bringing more products to swell the ever-growing traffic of the parent stem or main line. Engines of greater power have tried to cope with the demands of an ever-increasing traffic and have been assisted by such improvements as heavier rails, automatic airbrake, grade revisions, block signals and better terminal facilities. Finally, however, when congestion on some main lines became too great with steam-engine operation, it was necessary to add second, or even a third or fourth pair of rails.

The limitations of the steam engine are not so keenly felt upon branch or feeder lines with the infrequent small tonnage trains incident to this service. The congestion on main lines has, in many cases, however, become most acute, and it is under such conditions that the steam engine plainly imposes its limitations upon the physical and economic showing of a railway property. Appreciating the need of building new lines into new country to some limited extent, the big problem before us is to greatly improve the railway machine we have already created. We want cheaper and quicker transportation over existing tracks, more reliable service, less congestion at terminals and proper provision for the future growth of traffic that in the past has doubled every twelve years. This is a large order to place upon steam-engine operation, now constituting the foundation upon which our present railway system rests and which many think is one of the fundamental causes of its economic collapse.

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* Presented at a meeting of the Electrical Section held Thursday, February 24, 1921.

We have practically built up our national life around the possibilities and limitations of the steam engine, taking advantage of such improvements from time to time as the advance in its development permitted. But at all times the steam engine has been the determining factor in establishing the entire railway development and has fixed present standards of trainloads, speeds, delays, division points, labor conditions, wages, even location of road and the multitude of factors entering into the vast railway problem. And this big machine has arrived at the point where it costs so much to keep it running that even greatly increased rates will not pay the bill and leave enough over to pay a fair return upon the capital invested. In this respect, a fair return is placed by our government at the modest figure of 6 per cent. of present valuation.

If we are to continue to exchange our eastern manufactured for western raw products, the carrying charges over the intervening one to three thousand miles must be kept at a minimum. In no country in the world does one man's labor produce so much, and specialized communities cannot continue to exist as such without the cheapest kind of transportation to facilitate the movement of surplus product from one end of the country to the other. The answer to the present sleeping sickness attacking the prosperity of both railways and industries cannot be found in the merry race of higher transportation rates climbing after increasing labor and fuel costs.

We are facing the facts of an eight-hour basic working day, with time and one-half for overtime, greatly increased wages, fuel prices at levels never before reached and maintenance costs that are practically prohibitive. We are told that vast sums of money must be expended on construction and new equipment to make good the deficiencies of the war period and provide for future growth in traffic. But no assurance is offered that such material additions to capital account will result in reduced transportation rates, better service and a higher economic return upon a property already equal in value to our entire national war debt.

In fact, it is apparently not possible to make such fundamental changes in railway operation and economics as are evidently necessary to accomplish the desired results simply by investing still greater sums in the old steam-engine facilities that have, in the opinion of many, failed to advance with the needs of the times.

Such minor improvements in steam-engine design as are already available or in view do not hold promise of any real relief from present operating conditions. The steam engine seems destined to spend the greater part of the year tied to the coal bunker, water tank, round house, ash pit, and repair shop with too little time left for the actual haulage of trains. It is wasteful in man power, especially on heavy grade divisions, and in these days of high wages and short working hours, with severe penalty for delays leading to overtime, this low efficiency in utilizing engine and train crews is fatal to economic success. It is a notorious waster of fuel, burning a quarter of all the coal mined, and finally its cost of upkeep and depreciation are so high as to constitute a most serious percentage of the total operating expense.

Perhaps this may seem a rather sweeping criticism of the steam engine. On the contrary, such facts are well known, but perhaps not fully appreciated unless compared with the operating records of other types of motive power. The steam engine has held supreme in the railway field for so many generations that to some it seems heresy to question its exclusive right to dominate it for all time.

During the past twenty years serious competition has entered the field of steam railway transportation. Electric railways have taken over the short-haul passenger traffic and in addition has created travel that never was enjoyed by steam roads. The gas motor truck has captured a great part of the short-haul express movement at the expense of both the steam and electric railways. To be sure, this motor-truck traffic is partly a left-over from war conditions which demanded quick deliveries, regardless of cost, while it has thus far borne no reasonable portion of public road upkeep. Nevertheless, railways must reckon with short-haul motor-truck competition in the future to an extent not as yet clearly defined.

The driver of any flivver will declare that he dodges more tonnage carried on motor trucks over main public roads than is in evidence on the railways they parallel. When comparatively small trucks bumping over public highways, not too well maintained at the taxpayer's expense, can successfully compete with rail transportation, something has evidently happened during the past few years which calls for a readjustment of our previous ideas of transportation. It takes a pull of approximately 50 pounds to move a ton over the varying grades and surfaces of our highways. The same 50-pounds pull will haul 10 tons of load over steel rails. Moreover, trucking power is obtained from one of our most expensive fuels, and gasoline substitutes are already being eagerly sought after to supplement a product that is fast becoming inadequate to meet the growing demands.

The late J. J. Hill built up the Great Northern property by an early recognition of the fact that while receipts are proportional to ton miles, operating expenses are determined by train miles. While efforts to increase trainloads were most successful in building up that great property serving the needs of a new and sparsely settled country, does not the growing competition of the motor-truck cast serious doubt upon the wisdom of too close adherence to the same inflexible principle when applied to the conditions obtaining in the congested districts of the East? Admitting the lower expense of train crews with the heavier train loading, is it not possible that the delays inseparable to slow-drag freights have materially contributed to establishing the motor-truck industry that offers as its one chief asset quick delivery? In his efforts to reduce ever-increasing operating costs, has the railway operator been too busily concerned in running his huge transportation machine to fully observe the industrial needs of the country and appreciate the evident value placed by the shipper upon speed?

We must admit that the American visiting Europe for the first time is quite likely to look upon its railways as somewhat of a joke. The small cars, light engines and low tonnage trains contrast unfavorably with American practice as to size. Afterward, however, the interesting discovery is made that most excellent service is given to a densely populated country by these small frequent trains and that American methods would possibly not suit such conditions at all.

It is a wide jump from the motor truck on our public roads to European railways, but can we not learn the same lesson from each, and that is that our present railways do not properly serve the more congested districts through which they pass and that our railway directors have themselves to blame if they do not profit from a recognition of the fundamental facts underlying the growing menace of motor-truck competition? Quite evidently our railways, as now operated, do not provide the service our eastern shippers want.

Shall the short-haul freight traffic be surrendered to the motor truck as was the short-haul passenger business to the electric railway, thus leaving our steel highways free for heavy through-train movement only? Can such through traffic alone pay for the upkeep of the property? If not, what steps can be taken to compete for the short-haul business? These are most pertinent questions in view of the fact that many more millions are being spent in building macadam roads and motor trucks than are apparently available for railway betterment.

Electricity has amply proved its effectiveness in the operation of light high-speed trains in congested zones. Steam traditions of a busy track have been shattered by electric-train performance. With such successful examples before us as our elevated roads, subways and electrified railway terminals, there can be no dissenting voice raised to challenge the statement that the adoption of the electric motor introduces the means of making radical changes in steam-engine practice in congested terminals. Not only is the electric motor preëminently fitted to meet the needs of short-haul, frequent-stop service, but it gives opportunity to relocate and redesign the whole terminal railway property along lines impossible to the steam engine.

Contrast the Grand Central Terminal of to-day with that of 1906 before electricity had replaced steam. The air rights over the yards have become most valuable, huge buildings have been erected, adjacent property greatly increased in value and in fact a new residential, hotel and office centre has been created in what may now be called the centre of New York City. The Pennsylvania Terminal eliminates the handicap of the Hudson and the whole picture is rounded out by the growing subway facilities. In fact, New York City is being electrified—that is, as regards its passenger transportation—and a similar transformation is about to be commenced in Chicago with the substitution of electricity for steam on the Illinois Central.

But that is not all. The way has been shown to solve the equally vital problem of handling freight and express matter in city terminals. The very nature of a steam engine has banished the railway terminal to the outskirts of a city; or has it been that our cities have developed as far away as possible from an undesirable neighbor? In any case the steam terminal is not immediately adjacent to the shipper or centre of distribution, nor is it well adapted to the expeditious and economic handling of freight. Electric terminals, on the contrary, may be located with proper regard to the needs of the shipper, in the very centre of our biggest cities, if necessary. Tracks may enter terminal warehouses on two, three or more levels and use but a fraction of the real estate required for an open steam terminal yard. In other words, there are apparently just as great opportunities to effect a transformation in our freight terminal facilities as have already been partly completed in passenger stations and approaches. Furthermore, the solution of the freight terminal problem will go far towards settling the question of short-haul competition, and electricity opens the way to overcome the handicaps of the steam engine which is now blocking the further development of the transportation machine.

Approximately one-quarter of all the coal mined in the United States is consumed by our railways, and a great part of this fuel, estimated at possibly one-third of the total, is wasted in so-called standby losses in the 63,000 engines utilized in hauling out trains. The modern engine is equipped with all possible improvements designed to increase its fuel efficiency, but, nevertheless, its main purpose, to which everything else must be largely sacrificed, is to render reasonably reliable service in hauling trains under all conditions of weight, speed, grade and climatic changes. The fuel economies which it is possible to introduce in a moving structure cannot compare in effectiveness with the developments incorporated in modern electric-power stations. The restrictions of track gauge, wheel base, axle weights and running qualities of the steam engine must impair the effectiveness of its boiler plant. Furthermore, each steam engine is a complete individual power plant, subject to all the variations in load incident to hauling trains over a broken profile, with intermediate and terminal delays. The boiler must be kept hot at all times, regardless of whether the engine is doing work or not, thus giving rise to the standby losses that form so great a proportion of the total fuel consumed.

The electric locomotive, on the other hand, comprises in the electric motor the most efficient and flexible known means of transforming potential into mechanical power. The variations in load of each individual locomotive in operation are largely smoothed out when superimposed upon the average demands of possibly 50 or more other locomotives, with a resulting load curve at the power house supplying them all that is sufficiently uniform to insure the most efficient use of fuel. The steam turbine and auxiliary station apparatus have been developed to such a high state of efficiency that manufacturers' guarantees can be secured of eight pounds of water per electrical horsepower. Large power houses are in operation at the rate of 14,000 B.T.U's, or approximately one pound of high-grade coal per electrical horsepower-hour output.

Based upon the performance of sixty huge electric locomotives operating over nearly 700 miles of route on the C. M. and St. P. Railway, and on other facts of record, it has been estimated that the passenger and revenue freight tonnage of the United States could be hauled by electric locomotives for one-third the coal now burned under steam-engine boilers. Not even the most ardent electrical enthusiast advocates the immediate electrification of all our steam railways, but the above comparison is offered as a measure of the magnitude of the present wastefulness of burning fuel and the ultimate goal toward which the electrification movement is directed. In this connection, it is of interest to note that railway fuel carried in cars and steam-engine tenders equals approximately 20 per cent. of the total revenue freight tonnage carried over our rails, and practically all of this non-paying tonnage could be saved by electrification. The adoption of electricity, therefore, would immediately increase the carrying capacity of our railways a fifth by eliminating the railway coal-carrying business from the rails.

While our country boasts of its almost unlimited fuel reserves, and is wasteful to a degree, such is not the condition in other parts of the world. England, France, Belgium, Switzerland, Sweden, Italy and even bankrupt Austria—all have entered upon an immediate program having for its final objective the universal electrification of the state and privately owned railways in those countries. Shortage of fuel is the most pressing incentive, and available water powers will be utilized to the utmost. A constructive government policy makes such an enormous undertaking possible, and is in-marked contrast to the politics that have brought our own railways to such a sorry financial plight.

In many instances, congestion on mountain-grade divisions has reached such a point that additional rails must be laid to obtain the needed relief with continued steam operation. It is in just such service that the electric locomotive offers very great advantages. Drawing power from a practically unlimited source of supply and free from the structural restrictions of the steam engine, the electric locomotive may be built to deliver any tractive power at any speed required by the operating needs of the service. Steam engines are now in operation that will give a maximum draw-bar pull up to the limit or standard draft rigging, but the speed of such powerful Mallet engines is so low as to greatly restrict the rapid movement of freight over heavy mountain grades. Not only can electric locomotives develop equal pull, but sustain full tractive power at double the speed possible with the heaviest steam engine.

Thus while one St. Paul electric locomotive hauls a 3000-ton train up a 1 per cent. grade unaided at a speed of 15 miles per hour, it is quite probable that we may anticipate the early demand for still greater power. Indeed, draft gear on commodity freight cars at no distant date may be so improved as to permit hauling a 5000-ton train up a 1 per cent. grade. This would demand a tractive effort of 135,000 pounds at the drivers and an output of the electric locomotive of 5400 h.p. at a speed of 15 miles per hour. Higher speeds at the same tractive effort are entirely feasible; in fact, the manufacturers of electric locomotives would to-day contract to build such an enormous machine and guarantee its output with no hesitancy as to their ability to make good.

Full appreciation of this fact of the availability in one locomotive structure of power far in excess of anything possible with the steam engine, opens up unlimited opportunities for readjustment of present methods of operating our steam roads. In other words, instead of steam-engine railroading, as in the past, we are offered the opportunity to enter into an era of real unrestricted railroading with the motive-power lid removed.

The development of the more powerful electric locomotive is a determining factor in the matter of grade revision, double tracking and mountain-division operation. Not only does the operation of the electric locomotive greatly increase the tonnage-carrying capacity of present tracks and postpone for an indefinite period the day of laying additional rails under most difficult and expensive conditions, but it also greatly reduces the hazards of heavy-grade railroading by utilizing the so-called "regenerative braking" feature on down-grade movement. It is an impressive sight to witness a 3000-ton train being hauled up the 1.66 per cent. grade over the divide at Donald and dropped down 2000 feet at Piedmont on the 21 miles of 2 per cent. descending grade of the C. M. and St. P. without once using the airbrakes. The mechanical power developed by the descending train is "regenerated" and returned as electricity to the trolley to be used by some other train, instead of being wasted in heating brake shoes and wheels inevitable to the use of airbrakes. Besides eliminating much of the risks of grade movement, electric braking contributes to the relief of traffic congestion, as it permits using higher speeds on the down grades with safety.

One of the marked advantages promptly discovered in the electric locomotive is its great reliability and consequently low cost of maintenance. For a period of ten years, or until the high cost of living struck the electric locomotive as well, the 120-ton New York Central electric locomotives were maintained for approximately 3½ cents per mile run, a noteworthy achievement when compared with the upkeep of steam engines of equal power. Even during the year 1919 the St. Paul electric locomotives, weighing nearly 300 tons and making some 60,000 miles a year, were maintained for approximately 15 cents per mile run, or less than one-third the upkeep of Mallet engines of equal tractive power.

And so this discourse could continue to present facts showing the especial fitness of the electric motor for the varied needs of rail transportation. While our railways are used for the wholesale movement of passengers and freight, they are, nevertheless, engaged in the retail burning of fuel under 63,000 individual boilers with the waste inseparable to such a necessity. The adoption of electricity assures such a vast fuel saving that even the most careful estimates appear startling to those who have not studied the facts available.

Electrification of mountain divisions has demonstrated a large increase in single-track capacity, estimated by some to be at least 50 per cent. greater than possible to steam-engine operation. In many instances this improvement can be secured at a less expenditure than would be required for double tracking and also shows a greater return upon the new capital charge incurred.

Cold weather does not affect the electric locomotive at all, in striking contrast to the frozen steam engines of the winters of 1917–18, while its greater safety and reliability on grades are matters of record.

Electrified terminals and approaches to large cities should revolutionize present steam-engine practice, and not only effect economies in operation but greatly stimulate traffic by introducing radical improvements in facilities. In other words, terminal electrification offers attractive opportunities to both the holder of railway securities and the shipper.

With no immediate prospect in sight of any material reduction in the price of labor, its output must be increased, and electric operation has demonstrated its effectiveness in this direction both on the road and in the shop, together with complete elimination of coal and water facilities, ash-pits, turntables, round-houses, etc. In addition, locomotive division points may be indefinitely extended, and already runs of 440 miles are being made with a single electric locomotive.

All these improvements in the electrified railway property will cost large sums of money. In some items of operating expense, such as fuel, crews and maintenance, direct savings are effected of such magnitude as to show a reasonable return upon new capital charges incurred in electrification. The argument for electrification, however, is built upon a broader foundation than a direct return upon the investment involved. In fact, it has to do with the vital question of the future growth of our transportation system and its effect upon our national prosperity.

We have come to a period in our railway development where many regard the steam engine as inherently responsible for much of the physical and economic troubles now most painfully apparent. If we may correctly interpret the needs of our railways, they require a major operation rather than the application of a bit of plaster. The steam engine may well retire with full honors from a field which has outgrown it and give way to its younger rival. Youth must be served.

A SENSITOMETRIC STUDY OF THE REDUCTION OF DEVELOPING-OUT PAPERS.*

BY

LOYD A. JONES and C. E. FAWKES.

THE action of photographic reducers upon the silver deposits in photographic plates and films has been studied rather extensively by various workers in the field of photographic research. These investigations have been carried out both from the practical and theoretical point of view. Among the most prominent researches of this nature may be mentioned those by Luppo-Cramer,[1] A. and L. Lumiere and Seyewetz,[2] Stenger and Heller,[3] Deck,[4] Nietz and Huse,[5] and Sheppard.[6] Practically all of this work has dealt with the reduction of density in the case of photographic materials coated on transparent supports, such as plates and films, for not until a satisfactory method for paper sensitometry[7] was available could the usual *H.* and *D.* methods be applied to the study of the reduction of density in photographic printing-out papers.

Since it is evident that the quality of the photographic print may in some cases be improved by the proper reduction of density, it seemed advisable to investigate the effect of various reducers when used for this purpose. The problem is considered in this paper entirely from the sensitometric standpoint, very little attention being paid to the theory of the action of these reducers on the deposits, and all conclusions relative to the merit of the various reducers tried are based upon the consideration of the sensitometric curves rather than upon actual prints. The sensitometric method for the study of the characteristics of photographic materials has been discussed at length in previous papers (footnotes 5, 7, and 8), and to these the reader is referred for the details of such methods.

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* Communicated by Dr. C. E. K. Mees, Director. Communication No. 111 from the Research Laboratory of the Eastman Kodak Company.

[1] *Colloid Chem. und Phot.*

[2] *Bull Français, Soc. de Phot.,* 1901.

[3] *Zeit. fur wissenschaft. Phot.,* 1913.

[4] *Australian Phot. Rev.,* 1916.

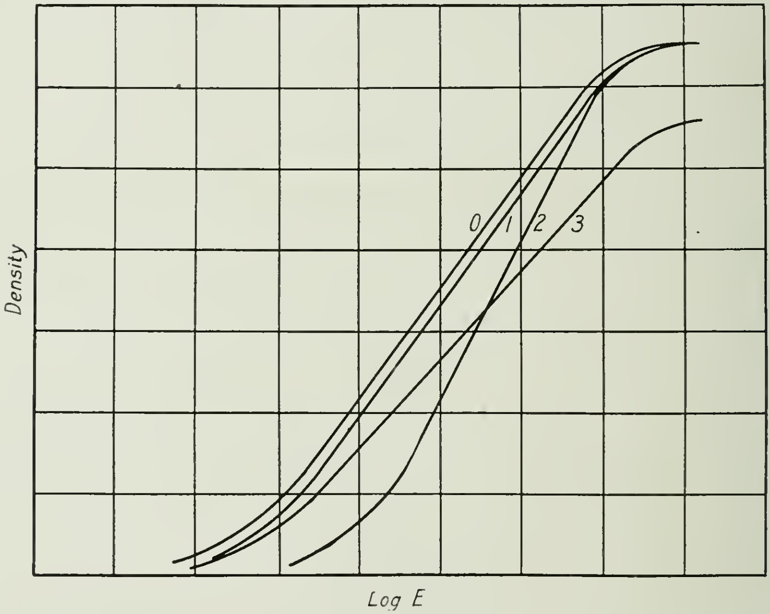
[5] *Brit. Jour.,* Oct. 27, 1916.

[6] *Phot. Jour. of Amer.* 55, 1918.

[7] Jones, Nutting and Mees: *J. Roy. Phot. Soc.,* Dec., 1915.

Excessive density in all parts of the print or in certain limited regions may result either from overexposure or overdevelopment of the print or because a paper of the proper contrast was not used in making the print. It is doubtful if reduction can completely correct the latter defect, but certainly some improvement may be effected. From a consideration of the shape of the characteristic curves of various papers, it will be seen that in order to improve the quality of the print in some cases reduction of density should be such as to cause a decrease in contrast, while in others the reduction should increase the contrast, while a third possibility may require reduction which will reduce the density in such a way that no change in the contrast is produced. These three general types of reduction may be illustrated by the curves shown in Fig. 1. Thus, if we consider the Curve 0 as the characteristic

FIG. 1.



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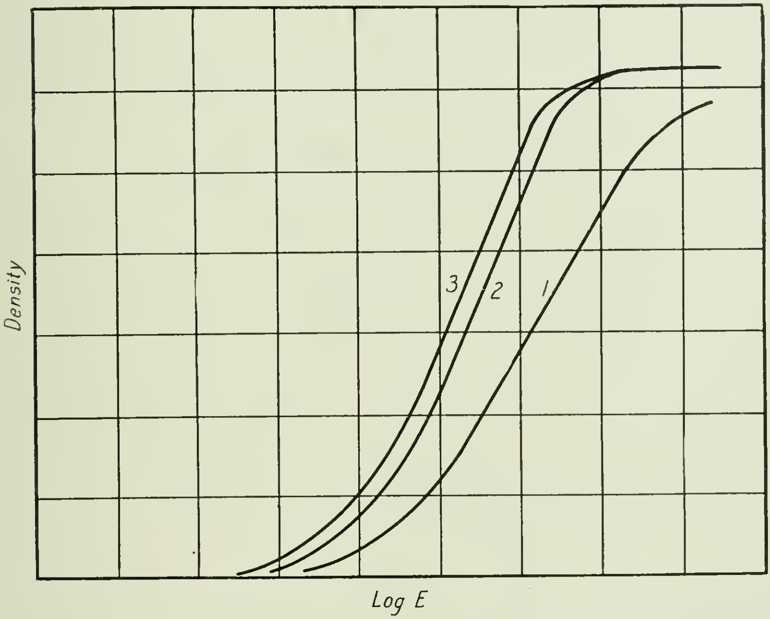
[5] JOUR. FRANK. INST., March, 1918, p. 389.

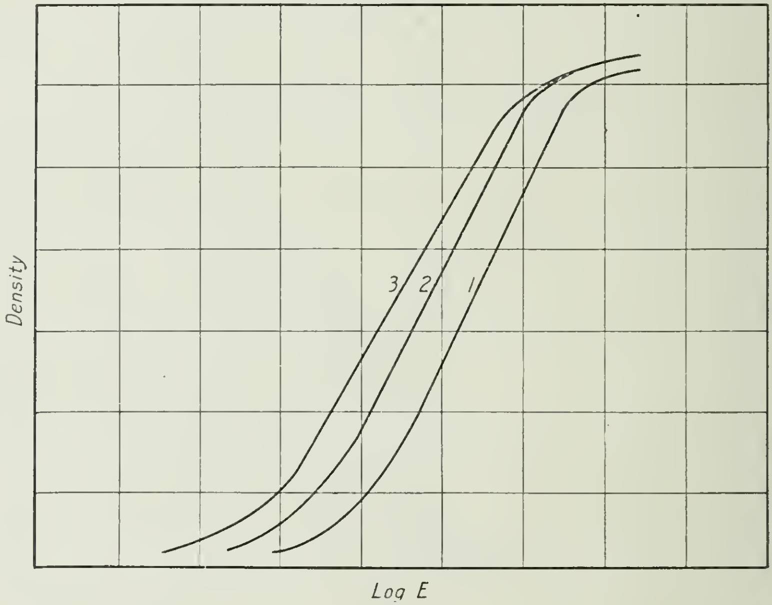
of the material considered, then Curve 1 will represent the result when this material is subjected to the action of a reducer producing no change in contrast. Such reducers will be referred to as Type 1. Curve 2 represents the result when the same material has been subjected to a reducer which produces an increase in contrast, this increase in contrast being caused by a more vigorous action of the solution upon the low densities than on the high. Reducers of this kind will be referred to as Type 2. Curve 3 represents a case of the decrease in contrast, and results from the proportional reduction of all densities, regardless of their magnitude: that is, each density is reduced to the same percentage of its original value. Reducers having this action will be referred to as Type 3. No distinct line of demarcation can be drawn between these various types, since some reducers have characteristics intermediate between those represented by the typical curves in Fig. 1.

FIG. 2.



In Fig. 2 are shown the characteristic curves of Iris Artura paper. Curves 1, 2, and 3 represent the change in density with increasing times of development. From the shape of these curves, it is possible to draw conclusions as to the action of the reducer, which can be used successfully to correct overdevelopment in the case of this material. It will be noted for the longer times of development that for the correction of overdevelopment a reducer of Type 1 will be necessary, while if it be desired to obtain results comparable with those resulting from underdevelopment in such a print a reducer of Type 3 will be required. In Fig. 3 are shown the characteristic curves of Velox, the different curves representing increasing times of development. It will be noted in this case that for the correction of overdevelopment a reducer of Type 1 is necessary.

FIG. 3.

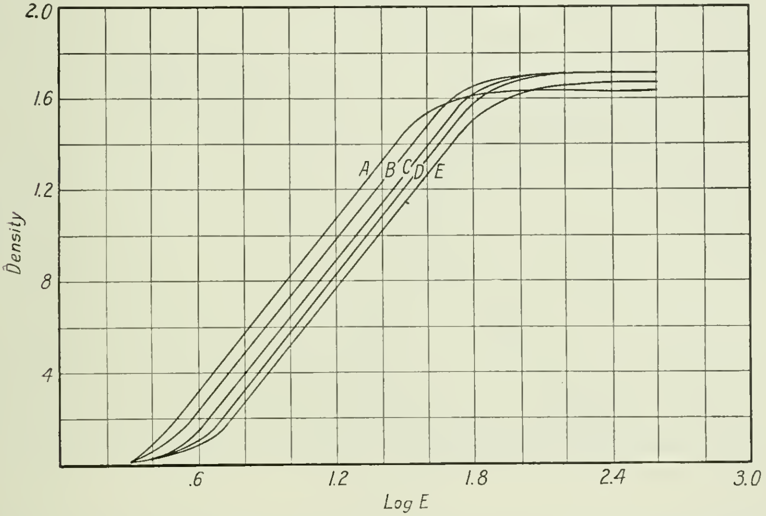


Ten reducer formulæ were chosen principally from the *British Journal Almanac* and prepared full strength. The list included permanganate, bichromate, Eder's and iodine-cyanide, whose action upon negatives is of Type 1, corresponding to the curve shift 0 to 1 (Fig. 1). Farmer's and Belitski's reducers were selected as being typical of Type 2, while sodium hypochlorite, ammonium persulphate and the Nietz-Huse proportional reducer were taken as representative of Type 3. As typical examples of the developing-out papers the following were chosen:

Paper	Grade	Relative Speed
Azo	E-Hard X	Medium Fast
Velox	Regular Velvet	Very Fast
Artura	Iris B	Slow

These papers were exposed in the non-intermittent sensitometer in the usual way, and strips consisting of twenty-six steps increasing in exposure by consecutive powers of the cube root of two

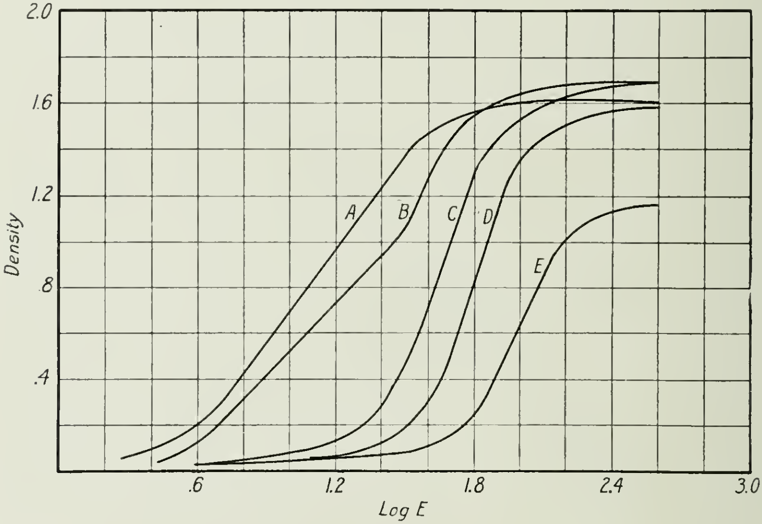
FIG. 4.



were obtained. These exposed strips were then developed in the recommended solutions, so as to obtain normally and overdeveloped results.

A number of preliminary tests were made with each reducing solution to find the dilution necessary to obtain uniform and controllable action. From these preliminary tests the most satisfactory concentration for use in the subsequent study of reduction was determined. These dilutions and the formulæ are given later in this report. All reduction was carried out at a temperature of 20° C. Careful observations were made relative to the color of the deposit resulting from the action of the reducing solutions for various lengths of time, and also upon the staining of the image and gelatine by the reducers and their reaction products. Some staining was observed, but in those reducers which were found to be otherwise satisfactory it was possible to remove these stains by returning the print after reduction to the ordinary acid-fixing bath for a short time, this, of course, being followed by washing and drying in the usual way. After being reduced, the reflecting power of the various areas of the sensitometric strips were read on the reflectometer and the characteristic curves plotted in the usual way. These curves were then compared with one plotted from the results obtained from the non-reduced strip. By a comparison of the curves thus obtained, information is secured from which it is possible to predict the action of the various reducers upon prints.

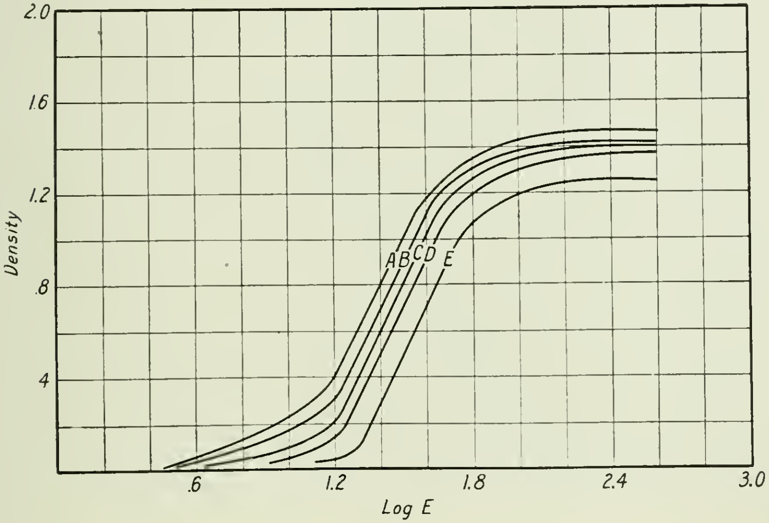
FIG. 5.



A. REDUCERS OF TYPE I.

1. Potassium Permanganate.—This reducer converts the silver of the deposit into silver sulphate, which is soluble in the solution. The reduction is rapid, and no stain is produced either in the silver deposits themselves or in the gelatine. With prolonged action it gives a slightly grainier appearance to the areas of low density. In Fig. 4 is shown a series of curves obtained with this reducer on Artura paper. It will be noted that the straight-line portions are almost exactly parallel to each other. Curve *A* was plotted from the unreduced strip, while *B, C, D,* and *E* were obtained by subjecting identical strips to the action of the solution for 45, 60, 90, and 120 seconds, respectively. It will be noted that the maximum black on the reduced strips is apparently higher than that of the unreduced. This is because the densities plotted are measured relative to the fog density of the paper. The action of the reducer cuts away this fog density and tends to give slightly higher maximum density when measured against the unexposed regions of the paper. The action of this reducer on Velox and Azo is the same as that on Artura (as shown in Fig. 4), with the exception that in the case of Velox there is slightly more reduction of the highlight regions. This reducer, as shown by the curve in Fig. 4, is an almost ideal corrective for cases of overdevelopment.

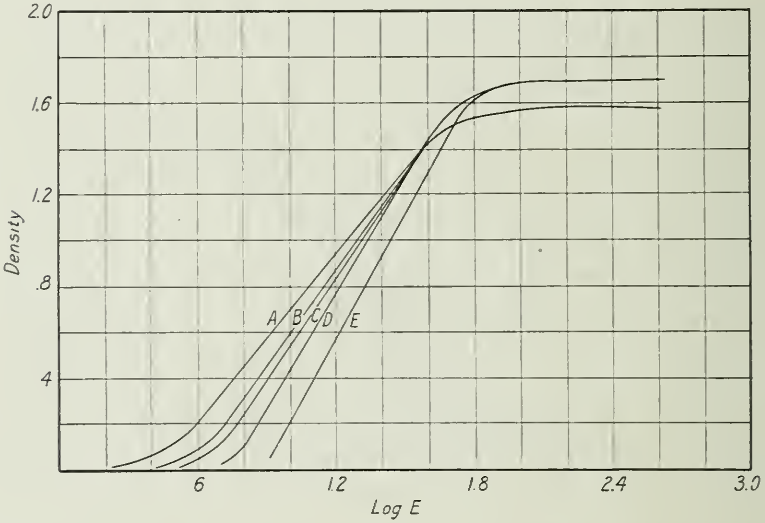
FIG. 6.



2. *Belitski's Reducer.*—The image is converted by the ferric oxalate and soluble chloride solution to silver chloride, which is then dissolved by the hypo in the reducer. The action is very rapid at the concentration recommended, and, although stainless and uniform in action, it seems to give a slightly brownish-colored deposit when the reduction is carried to any length. In the case of

slight reduction, this tendency to give brownish deposits seems to be entirely absent. On Artura it acts as it does on negatives, giving a transformation of Type 2—that is, reducing the lower densities more rapidly than the higher ones and therefore giving an increase in contrast. Upon Velox and Azo its action is of Type 1, the straight line portion of the curve remaining parallel to that of the unreduced strip. In Fig. 5 is shown a set of curves obtained from sensitometric strips made on Artura and treated with this reducer, the times of action being 45, 60, 90, and 120 seconds, respectively, for curves *B, C, D,* and *E.* In Fig. 6 are given the curves showing the action of this developer on Azo. These curves are almost identical with those obtained on Velox. It should be noted that while the straight-line portion of the reduction curves are practically parallel to that of the unreduced, the highlight densities are attached more vigorously than those of the halftone and shadows, thus producing a cutting away of the toe of the curve in the case of the reduced strips.

FIG. 7.



3. Iodine-Cyanide.—This reducer applied on prints falls in Type 2. Further reference is made in that classification.

4. Eder's.—This reducer was found to be unsatisfactory, owing to the unevenness with which action occurred.
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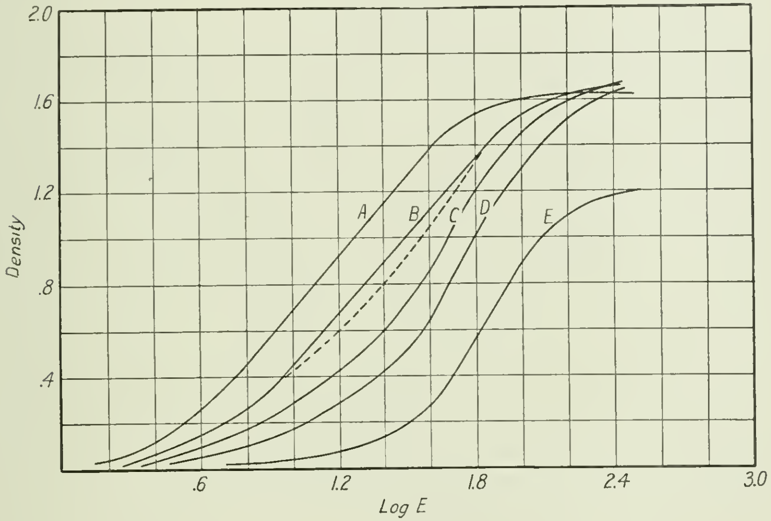
5. *Bichromate.*—This also was found unsatisfactory, owing to excessive staining of the gelatine.

B. TYPE 2.

1. *Iodine-Cyanide.*—The free iodine in the solution converts the silver of the image into silver iodide which is soluble in the potassium cyanide of the solution. This reducer acts rapidly, uniformly, and is clean and stainless. No mottling effect is noticeable even in the lowest density. It is, however, extremely poisonous, and therefore it is undesirable to recommend it for general use. In Fig. 7 are shown a series of curves plotted from strips made on Artura Iris and reduced in this solution. Curve *A* is that of the unreduced strip, while *B, C, D*, and *E* received treatments of 30, 45, 75 and 120 seconds. It will be noted that the upper portion of the curves are changed very slightly, while the highlight and lower half-tone densities are cut away, producing an increase in contrast. The action on Velox and Azo is identical with that on Artura. During the reduction, the paper stock of the print appears a brilliant blue, due to the presence of starch iodide which can be completely removed by soaking in an acid-hypo solution after the reduction is completed.

FIG. 8A.

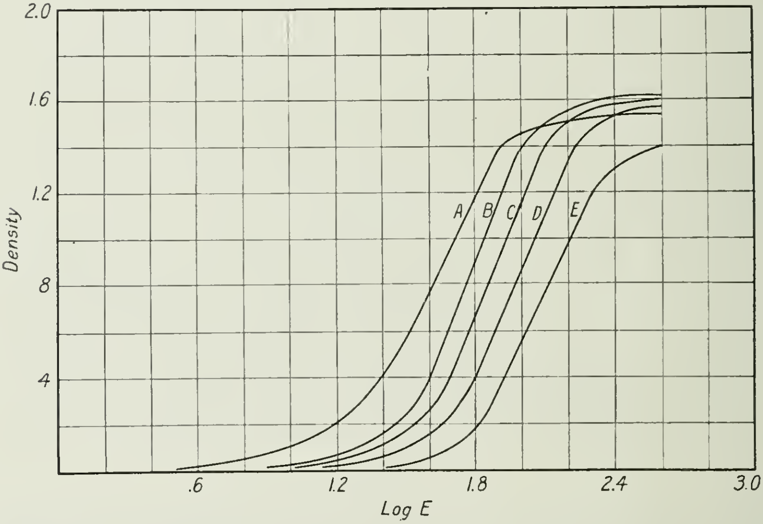


2. *Farmer's Reducer.*—The silver is converted by the potassium ferricyanide into silver ferrocyanide, which is soluble in the hypo of the solution. A slight staining of the gelatine was noticed in some cases, but in other respects the action is identical with that of the iodine cyanide. The curves shown in Fig. 7 are typical of Farmer's reducer on all kinds of paper.

C. TYPE 3.

1. *Nietz and Huse Proportional Reducer.*—The reduction in this case is due to a combination of the actions of ammonium persulphate and potassium permanganate. Each reducing agent retains its chemical identity. The permanganate attacks the lower densities while the persulphate is acting upon the higher densities. Used on prints, the action is very rapid, uniform and stainless. Its concentration can be adjusted to any particular paper reduction problem with great ease. In Fig. 8A are given curves plotted from strips made on Artura Iris treated with this reducer. In Fig. 8B are shown the results on Velox, and in Fig. 8C those obtained upon Azo.

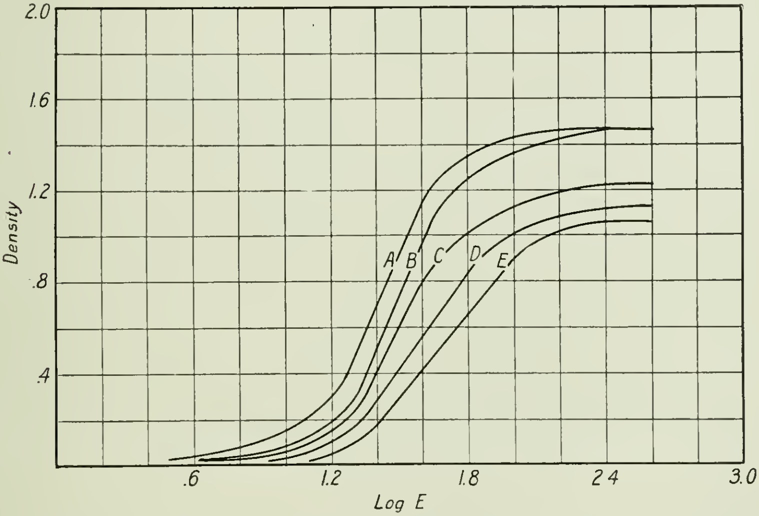
Fig. 8B.



2. *Ammonium Persulphate.*—Various attempts have been made to explain the peculiar action of this reducer. Luppo-

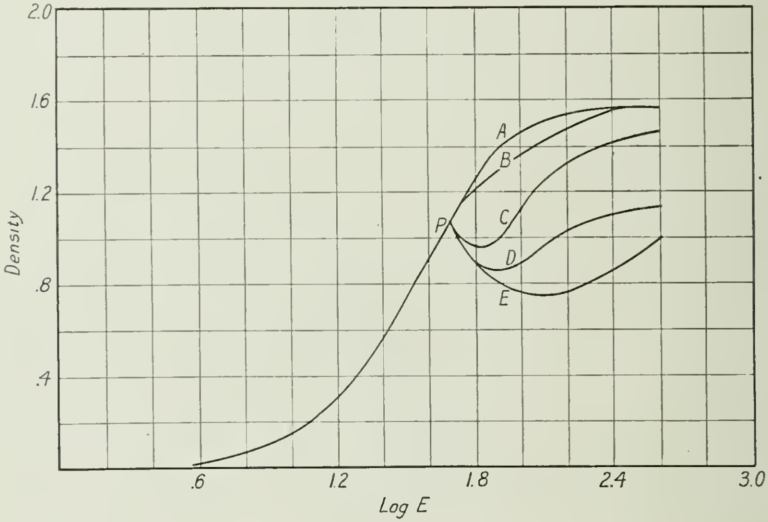
Cramer has advanced a protective colloid theory based on the idea that the chemical composition of the photographic image is dependent upon the exposure. The images having higher density are, therefore, in some way different from those of lower density, and this difference is of such a nature that the ammonium persulphate reducer attacks densities above a certain critical value very vigorously, while the action of lower densities is almost inappreciable. A catalytic theory of the action has been proposed by E. Stenger, which assumes a selective action on the higher densities due to the presence there of an excess of silver ions. In Fig. 9 are shown curves illustrating the action of this reducer on the Velox strips. It will be noted that above a certain critical density designated by the point *P* the action is very vigorous, while for densities lower than that no measurable action occurs. Strips reduced in this solution, therefore, have very peculiar density characteristics. For instance, a strip treated four minutes exhibits a density maximum in the half-tone regions, the shadows being cut away, so that they are actually lower in density. It is evident that this reducer is unsatisfactory for most purposes, although it is possible that it may be utilized to advantage in some special cases where it is desirable to reduce the shadow densities without effecting high-light and half-tone regions. By the addition of a soluble chloride

FIG. 8C.



or of silver ions (silver nitrate) to the reducing solution, the character of the action is changed radically, and the reduction becomes strictly proportional. In Fig. 10 are shown the curves obtained from strips made on Velox reduced in an ammonium persulphate solution containing 10 per cent. sodium chloride. Curves *B, C, D,* and *E* were obtained from strips which had received 2, 3, 5, and 7 minutes' treatment. It will be noted that the reduction is very nearly proportional, the action is uniform, and no staining of the deposit or gelatine is perceptible. It should be pointed out that the results shown in Fig. 9 were obtained by the persulphate reducer when made up with distilled water, the only difference in the solution used for obtaining results in Fig. 10 being the addition of 1 per cent. of sodium chloride.

FIG. 9.



SUMMARY.

1. Several reducers commonly used for the reduction of negatives have been studied and modified in such a way as to be applicable to the reduction of prints made on developing-out papers.

2. A classification has been made on the basis of the character of the modification in the characteristic curve obtained with the several reducers.

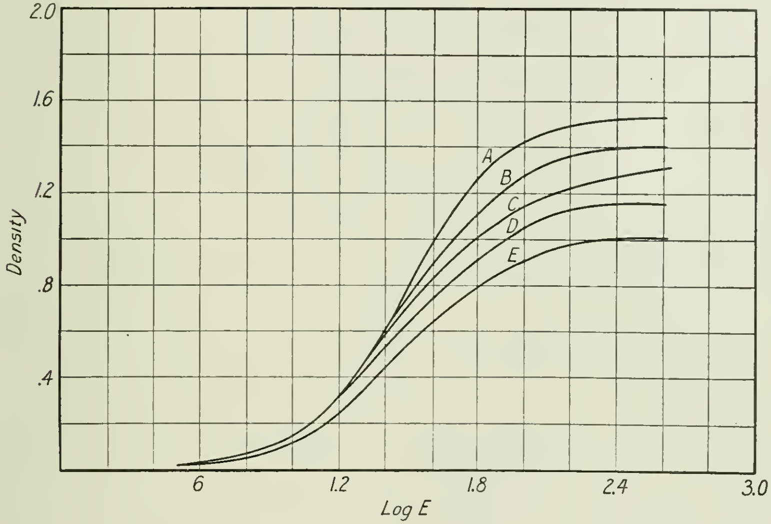
3. Observations have been made relative to the staining of

the deposit and of the gelatine resulting from the action of the reducer and its reaction products, and a means of removing the stain in most cases has been found.

4. The character of the action of a given reducer on negatives cannot, in all cases, be taken as indicative of what its action on prints will be.

5. Reducing solutions made up according to the formulæ appended to this report have been found to give satisfactory action on printing-out papers, the particular one to be chosen in any case depending upon the modification which it is desired to make in the print.

FIG. 10.



FORMULÆ.

Permanganate Reducer.

Potassium Permanganate	.5	gms.
Sulphuric Acid 10 per cent.	25	c.c.
Water	500	c.c.

Dilution for use: 1 part of solution in 13 parts of water.

Belitski's Reducer.

Ferric Chloride, crystals	6.5	gms.
Potassium or Sodium, oxalate	12.5	gms.
Sodium Sulphite	8	gms.
Water	200	c.c.

When ready to use, add to the above 3 gms. of oxalic acid crystals and agitate the solution until it turns green. Pour the supernatant liquid off the crystals and add to this clear solution 50 gms. of sodium thiosulphate. Dilute this solution 3 parts in 11 parts of water for working on prints.

Iodine Cyanide Reducer.

Iodine (10 per cent. sol. in Potassium Iodide)	25 c.c.
Potassium Cyanide 10 per cent. sol.	4 c.c.
Water	400 c.c.

For paper reduction take solution 1 part, water 10 parts.

Farmer's Solution.

Sodium Thiosulphate 20 per cent.	150 c.c.
Potassium Ferricyanide 10 per cent.	51 c.c.

Dilution for print reduction, 1 part in 3 parts water.

Nietz's Proportional Reducer.

Solution A.		
Potassium Permanganate	.125	gms.
Sulphuric Acid 10 per cent.	7.5	c.c.
Water	500	c.c.
Solution B.		
Ammonium Persulphate	12.5	gms.
Water	500	c.c.

For print reduction take 1 part A, 1 part B, and 4 parts of water.

Ammonium Persulphate Reducer.

Ammonium Persulphate	40	gms.
Water	500	c.c.
Sulphuric Acid	.53	c.c.
Sodium Chloride	.4	gms.

Dilution for print reduction: 1 part in 2 parts of water.

Rochester, N. Y.,
December, 1920.

THE THICKNESS OF WET PAINT FILMS.*

BY

A. H. PFUND, Ph.D.

Associate Professor of Physics, Johns Hopkins University.

In connection with the study of the hiding-power of paints, as revealed by the cryptometer,[1] the need of an instrument for determining the thickness of a single coat of wet paint has made itself felt. The field of application of such an instrument would be wide: (1) knowing the total thickness of layer necessary for complete hiding, a knowledge of the thickness of one coat would make possible a determination of the "number of coats"; (2) exposure tests could be carried out on paint or varnish films of known thickness; (3) the shrinkage of paint films upon drying could be studied; (4) when the air-brush is used, the thickness of coating might be controlled; (5) the hiding-powers of paints, such as "flat whites" and cold-water paints, which experience a marked change upon drying, might be determined; (6) the skill of a painter in applying uniform coats could be put to a severe test.

The usual method of evaluating the thickness of a wet paint-film involves the rather laborious procedure of determining, first, the specific gravity of the paint. Subsequently, a known area of plate-glass is coated with paint. The can, brush and paint are weighed to an accuracy of 0.01 gr. both before and after painting so as to yield the mass of the paint applied. A simple calculation yields the average thickness of the paint-film. Aside from the length of time involved in carrying out such a determination, the principal objection to this method is that it cannot be used if the constitution (and hence, the specific gravity) of the paint is unknown. Furthermore, the method cannot be used in checking up the actual performance of a painter.

These difficulties are overcome in the instrument about to be described. Advantage is taken of the circumstance that paint is a plastic solid,[2] whose "yield-value" is greater than the capillary forces introduced through the use of the instrument. The principle may be illustrated most simply by considering a uniform layer of paint upon which a glass plate, with one edge slightly raised, is placed. As shown diagrammatically in Fig. 1, the volume of paint, originally in the layer *ABCDA*, is crowded into the wedge form *ABEA*. Since the wedge-angle (α) is very small, the thickness (t) of the original film is given by the relation:

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* Communicated by the Author.

[1] Pfund: Jour. Franklin Inst., Nov., 1919, p. 575.

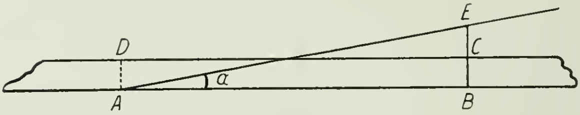
[2] Bingham and Green: *Proc. Am. Soc. Test. Mats.,* Vol. xix, Part ii (1919).

$$t = \frac{1}{2} \alpha L$$

where L is the length of the wedge wet by the paint, *i.e.*, the distance *AE* in Fig. 1.

Since the wedge calls for essentially plane surfaces to which the paint is applied, and since, furthermore, some of the paint is squeezed out from underneath the wedge, a symmetrical wedge was chosen. This is simply a convex, spherical surface which is forced through the paint layer. As shown in Fig. 2, the volume of paint originally in the layer *ABCKA* is forced into the meniscus *AEFGBA*. If the diameter (D) of the circular paint-spot be measured, and if the radius of curvature (R) of the convex surface be known, then, by performing a simple integration, it is found that the thickness (t) of the original paint-film is given by the relation:

FIG. 1.



$$t = \frac{D^2}{16R}$$

The final form given the instrument is shown in Fig. 3. A convex lens L whose lower surface has a radius of curvature of 25 cm. is mounted in a short tube T, which slides freely in an outer tube T_2. The compression-springs S keep the convex surface out of contact with the paint-film until pressure is applied to the top of T_1. This instrument, which is to be designated as the "Paint-film Gauge," is simply rested on a painted surface, and the lens is forced down as far as it will go. Upon releasing the pressure before removing the gauge, a circular spot is left on the gauge as well as on the painted surface. The diameter of the spot on the gauge is measured to 0.1 of a millimetre. If the spot is elliptical, the mean of the major and minor axes is determined. A series of readings on at least ten spots, judiciously distributed over a given area, yields a fair value of the average thickness of film. By referring to the table printed below, the thickness of the paint-film in mm. and the number of square feet which would be covered by one gallon of paint may be evaluated at once.

d = Diameter of paint spot on lens (in mm.).
t = Thickness of paint film (in mm.).

d In mm.	t Thickness in mm.	Sq. ft. per gal.
3	.00225	18,088
4	.00400	10,175
5	.00625	6,512
6	.00900	4,522
7	.01225	3,321
8	.01600	2,543
9	.02025	2,009
10	.02500	1,628
11	.03025	1,345
12	.03600	1,130
13	.04225	963
14	.04900	830
15	.05625	723
16	.06400	636
17	.07225	563
18	.08100	502
19	.09025	450
20	.10000	407
21	.11025	369
22	.12100	336
23	.13225	307
24	.14400	282
25	.15625	260
26	.16900	241
27	.18225	223
28	.19600	207
29	.21025	193
30	.22500	180
32	.25600	158
34	.28900	141
36	.32400	125
38	.36100	113

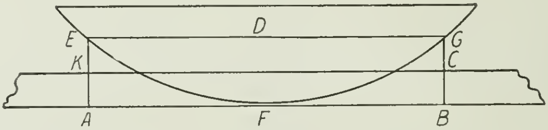
A number of experiments were carried out to check the accuracy of the paint-film gauge. In each case a known mass of paint was spread uniformly over a definite area of plate-glass, and the thickness of film was calculated in the usual manner. Different gauges and thickness of layer were used. The results are briefly presented in the following table:

	I	II	III	IV
Film thickness (by calculation)	0.0444 mm.	0.0402	0.0644	0.0638
Film thickness (by Paint-film Gauge) ..	0.0448	0.0390	0.0652	0.0638

Considering the roughness of the measurements, the agreement is surprisingly good. Equally satisfactory results were obtained on varnish films. The differences between the two sets of measurements rarely exceeded 3 per cent.

Having established the reliability of this instrument, it was sought next to determine whether or not different paints had different spreading rates. While it is obvious that a gallon of paint containing much turpentine and other "thinners" will be spread over a much larger area than an equal volume of a thick, creamy paint, it seemed worth while to test the performance of various painters with the same kind of paint. Accordingly, three different kinds of paint were prepared and each painter applied these to a clap-board panel whose surface had been previously primed so as to be impervious to the layer applied. The panel stood in an essentially vertical position, and each painter was asked to apply a characteristic "second coat." The results obtained are shown in the following table:

Fig. 2.



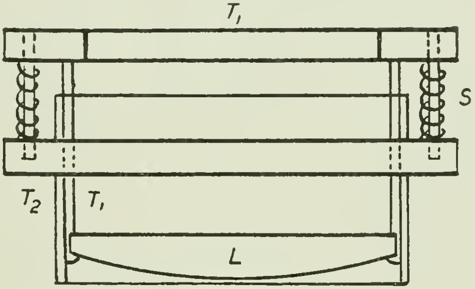
Character of paint		Hiding power	Spreading-rate			
			Painter A	Painter B	Painter C	Painter D
No. 1.	Lithopone, Zinc oxide 61.5 per cent. Linseed oil 35 per cent.	230 *sq. ft.* gal.	637 *sq. ft.* gal.	601	601	870
No. 2.	Zinc oxide, White lead 63 per cent. Linseed oil, 37 per cent.	232 *sq. ft.* gal.	580 *sq. ft.* gal.	730	630	790
No. 3.	White lead, 78 per cent. Linseed oil, 22 per cent.	276 *sq. ft.* gal.	434 *sq. ft.* gal.	710	790	830

Painter A finds a maximum spreading rate for paint No. 1, B for paint No. 2, and C for paint No. 3.

The paints were designated as having respectively "no tooth," "medium tooth" and "much tooth." Whether or not these characteristics affect the spreading-rate, seems uncertain from the above results. While, very probably, a theoretical value of spreading-rate might be obtained through the use of the plastometer,[3] it seems clear, that, in practice, greater differences exist between individual painters than between paints. While hiding-power and color are definite characteristics of a paint, the spreading-rate depends very largely upon the painter and is, therefore, in practice a variable quantity.

The shrinkage of wet paint-films may be determined readily by measuring the thickness of the wet film by means of the Paint-film Gauge and that of the dry film by means of a micrometer. While a detailed study of this problem is of interest, it was deemed of less immediate importance than the one dealing with the effect of shrinkage on hiding-power, particularly for those paints which become much brighter upon drying. This problem was attacked by coating a piece of plate-glass (11 x 13 cm.) with a flat-white paint upon which black spots, irregularly spaced, were marked. The entire surface was given a heavy coating of varnish, which was sandpapered smooth when dry. A metallic strip, 0.3 mm. thick, was glued to this surface at the edge of the plate, so that when a pool of paint was poured on the plate, it could be given a wedge-shaped form by leveling off the surface with a straight-edge (steel rule). The thickness of the wedge would obviously

FIG. 3.



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[3] Bingham and Green: *Loc. cit.*

vary from zero to 0.3 mm. While the paint is wet, record is taken of the position of the last spot visible and the film-thickness adjacent to this spot is determined with the Paint-Film Gauge. These data yield the hiding-power of the wet paint. Several other measurements of thickness at various distances from the metal strip are made so as to obtain a relation between film thickness and distance from metallic strip. When the paint is dry, the last spot visible is again sought, and the thickness of the *wet* paint-film, formerly overlying this spot is calculated. This, of course, yields the hiding-power of the *dry* paint. While this mode of procedure is less accurate than that resulting from the use of the cryptometer, it nevertheless makes possible a determination of hiding-power to an accuracy of 5–10 per cent. and solves a type of problem to which the cryptometer cannot be applied.

For lack of time, such numerical determinations were not made —only qualitative results were recorded. Separate strips of glass were also coated with the various paints which were tested for shrinkage. The drying was done rapidly over a radiator. Measurements of brightness on the wet and dry films were made with the Colorimeter.[4] The results obtained are shown in the following table:

Paint	Shrinkage	Brightness increase upon drying	Change in hiding-power upon drying
	Per cent.	Per cent.	
Commercial cold water paint	30	25	Very great increase
Zn O, turpentine	20	10	Marked increase
Zn O, gelatine water	40	5	Slight increase
Zn O, varnish	46	0	No change
Zn O, linseed oil. Drier	12	−1	No change
Commercial flat wall-finish	36	−5	Slight decrease

In spite of large variations in shrinkage values, the hiding-power does not vary with shrinkage but with brightness changes. This conclusion applies only in case that no chemical changes, producing a darkening of the paint-film, set in during the process of drying. In the majority of the above paints, the drying simply involves the evaporating of a fluid. If air-pockets are left, an increase in brightness results because of the smaller refractive index of air. While shrinkage undoubtedly has some effect, its influence is entirely overshadowed by the changes in brightness.

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[4] Pfund: Jour. Franklin Inst., March, 1920, p. 371.

SUMMARY.

1. A new instrument, the Paint-Film Gauge, has been devised to measure the thickness of wet paint-films. The attainable accuracy is better than 3 per cent.

2. The spreading-rates of different types of paints were determined by means of the Paint-Film Gauge. Variations introduced by the painters are greater than those introduced by the paints. In actual practice, spreading-rate is not a constant for a given type of paint.

3. Hiding-powers of paints, in particular those which become markedly brighter upon drying—increase as brightness increases and are but little affected by shrinkage of the paint-film.

JOHNS HOPKINS UNIVERSITY,
RESEARCH LABORATORY OF THE NEW JERSEY ZINC CO.

Properties of Gallium.—THEODORE W. RICHARDS and SYLVESTER BOYER, of Harvard University, have made a research on the properties of the metallic element gallium (*Journal of the American Chemical Society,* 1921, xliii, 274–294). Gallium apparently lies between indium and zinc in the electrochemical series, and may be precipitated from weakly acid solutions if sufficient current density be employed. After preliminary purification by electrolysis, gallium may be rendered free from zinc by ignition in a high vacuum or by crystallization; a product of constant melting point is thereby obtained. The melting point of the metal is 29.75° C. on the hydrogen scale. The density of solid gallium is 5.904, that of liquid gallium 6.095, both determinations being made at the melting point. On solidification, gallium undergoes an expansion of 0.00531 c.c. per gram. The solid element has a cubic coefficient of expansion of approximately 0.000055; therefore the density of the solid at 20° C. is 5.907, and the atomic volume of the element is 11.85. The compressibility of solid gallium is 0.0000020; the compressibility of liquid gallium is approximately twice that of the solid. The surface tension of liquid gallium, measured in an atmosphere of carbon dioxide at a temperature of 30° C., is 36.54 milligrams per mm. The latent heat of fusion of gallium is 19.04 calories per gram at a pressure of 173 megabars (approximately 170.75 atmospheres); and the melting point is depressed 0.00207° C. by an increase of one atmosphere in pressure.

J. S. H.

New Reagent for Sugar Analysis.—When a solution contains both glucose and lactose or milk sugar, the amount of each of these sugars present in the solution may be calculated, if the solution be titrated against Fehling's solution both before and after hydrolysis of the lactose. However, since prolonged boiling with an acid is required to hydrolyze lactose completely, mineral acids cannot be used for this purpose, for they further decompose the products of hydrolysis during the prolonged boiling. The new reagent, which has been used with success by E. HILDT (*Ann. Chimie anal. et appl.*, 1920 (2), ii, 78–80) to produce this hydrolysis, is benzenesulphonic acid, obtained by the reaction of sulphuric acid and sodium benezenesulphonate. To hydrolyze the lactose completely, the solution, containing not more than 1 per cent. of sugar and sufficient benzenesulphonic acid to render the concentration of the latter one-fifth normal, is kept for six hours at a temperature of 95° to 98° C.

J. S. H.

Railroad Reconstruction in France. (Information from *French Commission in the United States*, March 7, 1921.)—The following details of the condition of the French railroads and their reconstruction since the Armistice demonstrate the rapidity with which France has recovered from the effects of the war. Of the 2404 kilometers of double track line totally destroyed during the war, all have been completely reconstructed. To permit normal traffic along these lines, it was necessary to wholly rebuild 1400 signal towers, culverts and small bridges of the total of 1503 destroyed. In addition, of the 2785 kilometers of single track line destroyed, 1810 have been entirely reconstructed and opened to traffic. Work on the remaining 975 kilometers is at present being carried out, but is progressing more slowly because double track line is being built instead of the single track line.

The number of locomotives in France at the signing of the Armistice in service was 14,537. On December 31, 1920, this number had increased to 18,429, of which 14,827 were French, 1679 German, 1299 of the Pershing type, and 624 of the American Government type. Orders for 1200 locomotives are at present being carried out. The number of freight cars at the disposal of the French railroads in November, 1918, totaled 410,308. On the 31st of December, 1920, this number had increased to 518,810, of which 432,038 were French, 48,891 German, 18,194 of the Pershing type, and 19,687 American Government type. Work is at present being carried out on 2500 freight cars for various roads.

The figures for the railroads of Alsace-Lorraine are not included in the above total. These railroads have at their disposal 1566 locomotives and 42,297 freight cars. They are to receive from Germany under the terms of the Peace Treaty a further 289 locomotives and 10,000 freight cars.

THE VECTOR SLIDE-RULE.*

BY

A. F. ZAHM, Ph.D.
Bureau of Construction and Repair, U.S.N.

Preface.—In uniplanar analysis one often has to find the magnitude and line of a vector when given its components and its moment about a point. For example, from the lift and drag of an ærofoil and its moment about a pivot one may have to plot the resultant force upon the ærofoil profile. This can be done expeditiously with the slide-rule here described. Also the moment of the vector about another point, and its shift with changing incidence of the ærofoil, can be read on the rule.

Description of the Instrument.—The vector slide-rule, as shown in Fig. 1, comprises a straight scale, preferably transparent, pivoted on a sheet of cross-section paper, and bearing a small slide like a T-square. A fine line is drawn centrally on the bottom of the ruler and passing through the pivot axis; and a like line is drawn on the blade of the T-square. The paper has at least two scales; a circular one about the pivot, and a linear one on a base line through the pivot lengthwise of the sheet. Others can be added to facilitate reading. The large circle shown is used for greater precision in reading small angles.

Magnitude and Direction of the Resultant.—To find the magnitude $\sqrt{L^2 + D^2}$, of the resultant R of the lift L and drag D, rotate the ruler till its centre line passes through the point L, D, and read the value on the ruler scale; to find the direction of the resultant, that is the angle γ whose tangent is D/L, read where the centre line crosses the graduated circle.

Line of the Resultant.—To draw the resultant on a profile page of the ærofoil, when the moment M is known, press the given centre of moments for the profile upon the steel pivot under the rule, and orient the page as shown in the photograph; set the rule at the angle $\gamma - i$ to the base line, where i is the angle of attack; set the edge of the slide at the distance M/R, and it will coincide with the desired line of the resultant R, as seen in the photograph. This R, it will be observed, is normal to the one mentioned in the preceding article; because the ruler was first used to compute R,

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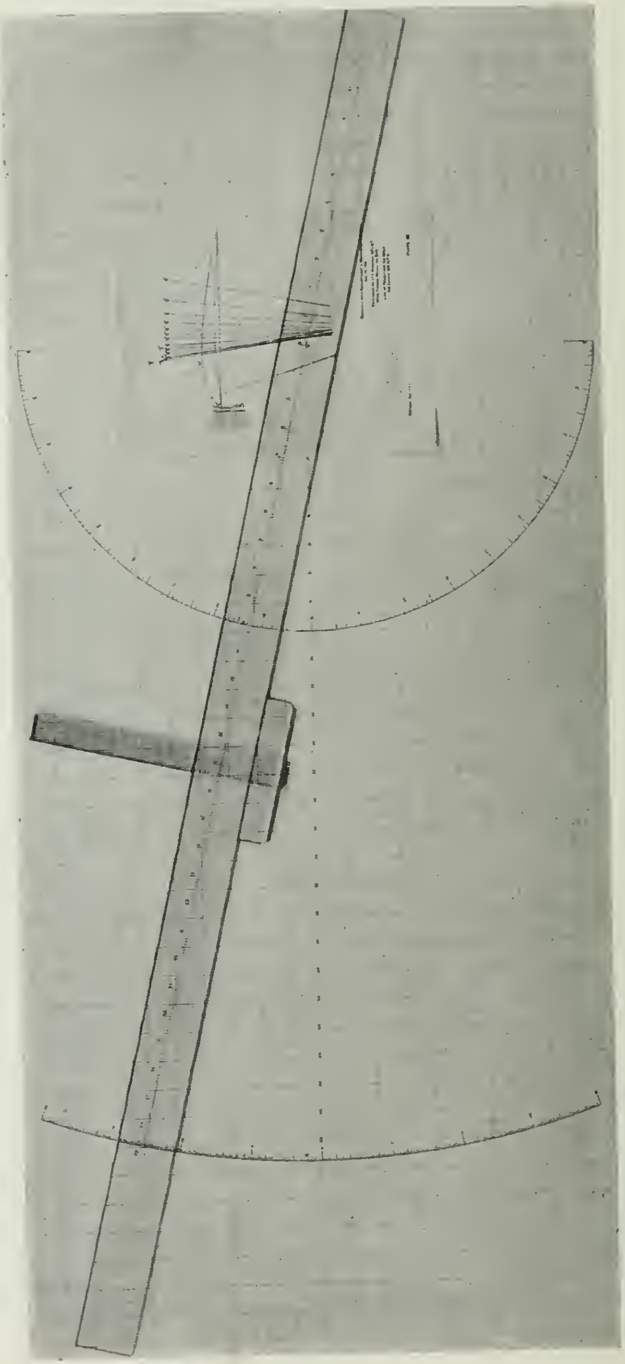
* Communicated by the Author.

FIG. 1.



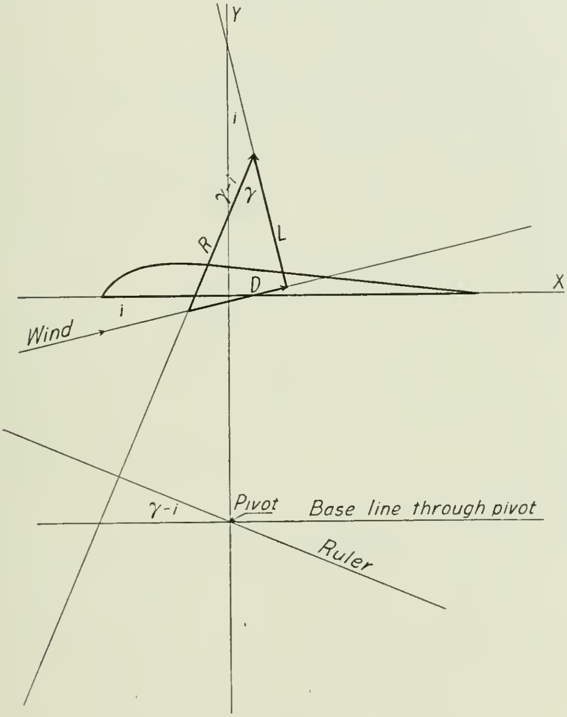
The Vector slide-rule.

then to guide the T-square slide in drawing R in a more convenient orientation.

Should the profile diagram be n times the size of the ærofoil section, $n\,M/R$ may be used with the same ruler scale, or M/R may be used with a special n-fold scale on the ruler.

Centre of Pressure.—The centre of pressure travel along the chord can, if the page is transparent, be read directly on the underneath section paper, at the points where the vector R crosses the chord, allowance being made for n. Also perpendiculars erected at those points, by aid of the slide and an incidence scale on it, have their tops on the centre of pressure curve, which can be drawn on the same page or on a superposed transparent one.

FIG. 2.



Slope of ruler when T-square is parallel to R.

Moment About Any Point.—The moment arm 1, about any other point than the pivot can, when R is drawn, be read directly on the centre-line scale as the distance of said new point from the slide, with due allowance for n. Then $R1$ is the moment.

Multiplication and Division.—To find the quotient $D/L = x$ of any two quantities, lay the centre-line of the rule through the point L, D, and read where it crosses a perpendicular to the base line at any decimal distance, such as 1, 10. For obviously $D/L = x/1$ or $10x/10$. To multiply D by L reverse this process.

Alternative Designs.—The ruler may slide over a circular guide having its centre at the pivot, and carry a try-square slide, thus leaving out the pivot and that part of the ruler which covers its immediate neighborhood, where the vectors are massed. But sometimes the given pivot is well away from the ærofoil, so that the vectors need not cross the ruler.

Again the farther end of the ruler may have crossing it a circular arc with a slide which can be set at the angle i from the base-line, that is $\gamma - i$ from the centre line. Then to draw R the whole is rotated till this slide coincides with the base line, thus setting the ruler at the proper angle $\gamma - i$ to the base. Substantially such an instrument, known as a propeller slide-rule, was described in the JOURNAL OF THE FRANKLIN INSTITUTE for November, 1917.

Geometric Proof.—If the foregoing operations have any novelty, it is in the structure and manipulation rather than the principle of the instrument. Still one may explain why the ruler is set at the angle $\gamma - i$ when drawing R. As seen in Fig. 2, R inclines γ to the lift, and the lift i to the vertical. Hence R and the T-square incline $\gamma - i$ to the vertical, and the ruler inclines the same to the horizontal.

Precision.—Easily made formulas give the above values more accurately, and nomograms accurately enough. Still instruments are needed to draw R. The present method is as precise as the draughtsman can see to plot the results, and is expeditious with little mental effort.

Use as Trigonometer.—The present instrument obviously can be used as an ordinary trigonometer for the solution of plane right triangles. That is if any two of the five elements—the sides and acute angles—be given, the remaining three can be read on the scales. The addition of a second ruler suitably placed would adapt the instrument to the solution of oblique triangles, as shown in the present writer's article, " Steering Aircraft at Sea," in the *Scientific American* for July 25, 1914. The reader may also refer to Appleton's Dictionary for a sketch of a plane trigonometer having a rectangular base sheet with angle scale about its sides, and a ruler pivoted at one corner.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

PROGRESS REPORT OF THE NATIONAL SCREW THREAD COMMISSION.[1]

(Authorized by Congress, July 18, 1918, H. R. 10852.)
As approved June 19, 1920.

[ABSTRACT.]

IN the Progress Report of the National Screw Thread Commission the following fundamentals have been established:

1. Definitions of screw-thread elements and all terms entering into screw-thread standardization.
2. A standard thread form. Thread angle = 60°; flat at crest = 1/8 pitch.
3. An adequate system of screw threads, consisting of a coarse-thread series and a fine-thread series.
4. Four kinds or classes of fit, with allowances and tolerances for three of the four classes established.
5. An adequate gauging system for inspecting the manufactured product.

The definitions adopted are in accordance with the best American usage.

The thread form adopted is the so-called U. S. or Sellers form, which is in nearly universal use in this country and is much used in other countries.

In the thread system adopted, the coarse-thread series comprises the so-called U. S. series of pitches and diameters, supplemented below one-quarter inch by the A.S.M.E. special machine screws. The fine-thread series comprises the S.A.E. diameters and pitches supplemented below one-quarter inch by the A.S.M.E. regular machine screws.

The four classes of fit adopted are: Class I, Loose fit; Class II, Medium fit; Class III, Close fit, and Class IV, Wrench fit.

Class I is intended for the roughest kind of bolts and nuts, where a very free fit is desired and a certain amount of shake or play is not objectionable.

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* Communicated by the Director.

[1] Miscellaneous Publications No. 42.

Class II is subdivided into II-A regular and II-B special. II-A is intended for the ordinary grade of machine work, where a good fit and strict interchangeability are demanded. This class of fit is intended to cover the great bulk of good grade machine work. Class II-B is intended for the highest grade of automobile and aircraft work.

Class III is intended for a very accurate precision fit. This class of work will require specially selected tools and equipment, and possibly some selection of parts in assembly.

Class IV is intended for work to be assembled with a wrench, or to be permanently set, as in the case of engine studs. The Commission was not in possession of sufficient data for the establishment of allowances and tolerances for this class of fit.

The above four classes of fit are arrived at on the basis of a uniform minimum nut for all fits. That is, the minimum nut is the same for all fits, and the necessary difference in dimensions of screw and nut in order to secure the desired looseness or tightness is obtained by changes in the diameter of the screw. This method of standardization reduces to a minimum the number of tap drills, taps, and gauges necessary to produce interchangeable work.

The gauging system adopted insures strict interchangeability in the finished product. This is accomplished by setting up, at the maximum and minimum size of each part, a dead line over which the dimensions must never pass.

The report has been more fully abstracted in *Mechanical Engineering* (Journal of A.S.M.E.), June, 1920; *Machinery*, July, 1920, with certain corrections in the August number; *American Machinist*, September 9 and 16, 1920, and is given in full in the official report.

PYROMETRIC PRACTICE.[2]

By Paul D. Foote, C. O. Fairchild and T. R. Harrison.

[ABSTRACT.]

In the preparation of this volume the primary object has been to present information which is useful in the choice and operation of pyrometric installations. Enough of the underlying theory has been included to make the principle of operation of each type of instrument readily understood.

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[2] Technologic Paper No. 170.

Special stress is laid upon refinements of construction and installation and precautions for operation, many of which are easily overlooked with the result that serious errors may be introduced.

The working temperature scale is reproduced in different ranges by different types of thermometer or pyrometer, and statements are made as to the agreement between the scales of these instruments and the thermodynamic scale, which is known as the ideal temperature scale. The freezing and boiling points of pure materials are used in calibrating the instruments.

In the section on high-temperature thermometry consideration is given to mercury thermometers when used without protection and also when mounted in metal protecting cases for industrial purposes. Indicating and recording instruments operated by vapor, gas, or liquid pressure and those operated by bimetallic springs or the differential expansion of graphite and metal are considered.

Several types of thermocouples are described which are suited to different ranges of temperature and conditions of use.

Thermoelectric indicating instruments are of three general types: those operating upon the galvanometric principle, those operating upon the potentiometric principle, and those operating upon a combination of these two principles. A galvanometric instrument is subject to errors due to changes in resistance of the leads and thermocouple. A number of different devices are discussed for minimizing or avoiding such errors.

The potentiometric principle is capable of much higher precision than is the galvanometric principle and must be employed where highest refinement is necessary. The fact that the principle is capable of higher precision, however, by no means indicates that it always renders higher precision. The performance depends upon the design and construction of the individual instrument.

The deflection potentiometer combines the rapidity of the galvanometer with the precision of the potentiometer. The gain in rapidity increases as the range of the galvanometer is made nearer to the full range of the complete instrument, while the precision of which the method is capable, decreases accordingly.

The e.m.f. developed by a thermocouple depends upon the temperature of the cold junctions as well as that of the hot junctions, hence the cold junctions must be maintained at a fixed temperature or some correction method must be adopted in order that the hot-junction temperature may be determined. To avoid the necessity of applying a correction to each reading, a number of automatic or manually operated cold-junction compensating devices have been developed.

In order that thermocouples be interchangeable, thus permitting necessary renewal of worn-out couples, all couples of a given type should have uniform thermoelectric properties. Where this has been impossible, a number of devices have been resorted to with a view to making the couples interchangeable. Many of these devices might easily cause greater errors than would be caused by using the couples without the devices. However, experience in manufacture is rapidly eliminating the necessity of any such arrangement.

Many industrial plants are equipped with large thermoelectric installations, which may include indicators, recorders, temperature control devices or automatic signaling apparatus. For good service a high grade of material and construction is required. The method of connecting several thermocouples to a common return wire is subject to large errors, and its use is seldom or never justified. Many wiring diagrams of typical installations are shown. In some wiring systems recorders are arranged to be connected to successive couples, and means is provided for connecting an indicator to any one of the couples at will. If the recorder and indicator are of the galvanometric type and the instruments read correctly when connected singly, the readings will be in error when the instruments are connected to the same couple at the same time. This error is small with low-resistance couples and leads connected to high-resistance galvanometers.

Compensating leads are often used to extend the cold junctions of couples to a point having approximately constant temperature or to a cold-junction compensator. The zone box and junction box effect a saving in the expensive compensating lead wires in the cases of single couples and multiple installations respectively. If a buried cold junction is used, its temperature should be determined at different seasons of the year.

The depth of immersion of a couple in a furnace is a matter of importance. Often a couple is purposely insufficiently immersed in order that its readings may be proportional to the temperature under consideration without the couple being subjected to the extreme temperature of the inside of the furnace.

It is rarely the case that a thermocouple can be used without protection. The limitations of the protecting tube more often than of the thermocouple, govern the usefulness of thermoelectric pyrometry. Various protecting tubes are described.

Optical pyrometers make use of the intensity of the radiation within a narrow band of the visible spectrum which is emitted by the body whose temperature is to be measured. This intensity varies not only with the temperature but also with the emissive power of the substance.

Optical pyrometers are calibrated to read the temperature of a black body. Fortunately many substances and the inside of furnaces usually require little or no corrections for departure from ideal black-body conditions. For other substances and conditions corrections must be applied.

For very high temperatures the intensity of radiation is reduced by an absorption glass. Tables of emissivity and true temperatures versus observed temperature for a number of substances are given in the text.

Radiation pyrometry differs from optical pyrometry in that the total radiation coming from a body is made use of. It is subject to the effect of emissive power and also requires a number of precautions which are not necessary in optical pyrometry. Radiation pyrometers may be made recording, however, while no recording optical pyrometer has yet been produced.

Resistance pyrometers are often used in certain classes of industrial work. Platinum wire is decidedly the most desirable material to use as the thermometer bulb, though nickel is employed to some extent in the industries, especially below 300°C. Several designs of measuring instruments are described, as are different methods of connecting to the bulb for the purpose of minimizing or eliminating errors due to lead resistance and to resistance at dial contacts within the instrument. These instruments may also be made of the deflection type and as recorders.

Through the use of recording pyrometers much valuable information may be obtained which leads to improved processes, increased uniformity and quality of product, reduction of cost of production, etc. The leading recording instruments are shown in cuts and described in detail in the chapter on recording pyrometry.

Transformation-point indicators and recorders are treated at some length, along with different methods of interpreting the data.

The meaning of temperature control may be extended to cover not only the control of temperatures but also the control of processes through a knowledge of the temperatures involved. In this sense it has a very wide interest. This section is not confined to a description of the apparatus used but enters into this broader phase of the subject.

The subject of melting-point methods is treated at length. The general classes of substances considered under this heading are metals, alloys, salts, and refractory materials, and for the temperature measurements, thermoelectric resistance, and optical pyrometers are discussed. Where substances of known melting points are employed, the methods are equally applicable to the calibration of the pyrometers being used. Tables of melting points are given.

Detailed information is presented as to the most suitable type of pyrometer to be used, the proper crucible and atmosphere for many materials, and suitable furnaces for different classes of work.

Complete information is given for the calibration of all of the important high-temperature measuring instruments which are used industrially, and suitable apparatus and accessories are described for each type of calibration. High-temperature thermometers may be calibrated by immersion in vapors of various boiling liquids or by the more convenient comparison method. Suitable comparators and others details are considered.

Thermocouple calibrations are either primary, where the melting points of several metals are used, or secondary, where comparison is made with other couples. All thermocouples should be annealed before testing. Homogeneity tests are also often necessary.

Beside the ordinary primary and secondary calibrations, numerous methods are described for checking thermocouples at only one or two points. The method is described for welding thermocouple junctions. The method of calculation of cold-junction corrections is also explained. Many measuring instruments for thermocouples are equipped with cold-junction compensators. This is often very desirable, but unless certain precautions are taken errors are likely to be introduced when standardized thermocouples are used with such instruments, or when these instruments are calibrated alone or in conjunction with thermocouples. Proper methods of procedure to avoid such errors are considered in detail.

Optical pyrometers are usually calibrated by the secondary method, where the pyrometer under tests is compared with an instrument which has been accurately calibrated. A precise and satisfactory primary calibration requires considerable technique and is not necessary except for special research work in the laboratory when the highest possible precision is required. Methods for both primary and secondary standardizations are considered.

For precision work radiation pyrometers must be standardized and used with extreme care. It has been found that many of the instruments are subject to peculiar errors requiring for their elimination rigid specifications in the method of calibration and use.

Primary calibrations are made by sighting into a specially designed "black-body" furnace, the temperature of which is measured by thermocouples. Secondary calibrations are made by sighting the instrument to be tested and a standardized instrument on the same source.

If an accurately calibrated resistance-measuring instrument is employed, the most precise method of standardizing a pure platinum resistance thermometer is by observations of the resistance at the temperatures of melting ice, steam, and sulphur vapor. A thermometer thus calibrated defines the temperature scale in the range where temperatures are most accurately known. Thermometers with indicators may be calibrated by secondary methods.

In the section on industrial applications of pyrometry no attempt is made to give all the applications. In fact many of the most important applications are omitted. The object of the section is to consider some of the applications which offer peculiar difficulties.

In this connection are treated the applications of pyrometry to glass manufacture, glass annealing, rotary Portland cement kilns, ceramic processes, coke manufacture, and steel manufacture. In an appendix are given conversion tables from Fahrenheit to Centigrade and vice versa, and other useful data.

THE TESTING OF PAPER.[3]

[ABSTRACT.]

This circular is published to meet the requests for information in regard to the testing of papers, since the interest in this subject is steadily increasing.

It contains information relating to the methods of testing paper and the apparatus employed in the paper laboratories of the Bureau of Standards for the routine testing of paper. The introduction discusses the size and importance of the paper industry and briefly considers the various fibrous raw materials for paper manufacture. Grasses and crop plants are referred to, and it is brought out that their use on a commercial scale is largely dependent on the cost of production. A rough classification is made of paper; it is divided into (1) boards, (2) building, (3) blotting, (4) book and cover, (5) news and hanging, (6) tissue, (7) wrapping, (8) fine (writing, bond, etc.), and (9) specialties. Paper is defined as a matted or felted structure of fibrous material, formed into a relatively thin sheet.

The value of paper testing is brought out, and it is emphasized that different testing methods are necessary for paper for different uses. By this is meant that, for instance, different kinds of physical tests are necessary for different types of paper, such as tissue and wallboard. For wrappers and envelopes, a tearing test is desirable, since such papers should be made to withstand a strain applied in that manner. A brief summary is given of suggested methods of developing specifications for paper. These suggestions are broad in scope and must be somewhat modified to meet particular conditions.

The physical qualities of paper are affected by changes of temperature and humidity, and a testing room with constant conditions of 70°F. temperature and 65 per cent. relative humidity is used. The degree of change due to atmospheric changes has not yet been worked out. A convenient form of rack for conditioning paper is illustrated. The following methods of testing the physical qualities of paper are given in detail with illustrations: weight, thickness, bursting strength, tensile strength, folding endurance, tearing strength, absorption, and transparency. These methods are so given that they may be of use in any laboratory testing papers. The accuracy of some of the methods is given, and it is emphasized that at least ten tests should be made and an average obtained.

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[3] Circular No. 107.

Under chemical testing are given the methods of determining the percentage of ash in paper and the amount of sizing. Two methods are given for the quantitative determination of rosin in paper, one of which is quicker but not so accurate, yet useful for control work. Qualitative tests for the various kinds of loading material are outlined. Qualitative tests for various sizing materials, such as rosin, starch, and glue are also given.

In regard to the microscopical examination and estimation of the fibres of which paper is made, the procedure is given in detail. The formula for the zinc-chloride iodine stain is given, and recommendations are made as to its use. It is almost impossible to describe this method, since much experience is necessary before accurate determinations can be made. The estimation method, with the use of standard mixtures carefully made up, is strongly recommended for speed and accuracy for routine testing. Several microphotographs illustrate representative wood fibres and show how the markings and shapes can be easily studied.

A working bibliography of useful books, periodicals, and government publications is included, but no attempt is made to make it complete. Recommendations are made as to size of sample to submit for test, and a fee schedule is given. The importance of proper sampling of paper is emphasized and instructions given as to recommended methods.

SAND-LIME BRICK—DESCRIPTION AND SPECIFICATION.[4]

[ABSTRACT.]

SAND-LIME brick is a building brick made of sand and lime. It was first produced in the United States in 1901. By the action of steam under pressure, the lime is caused to combine with some of the sand, forming a hydrated calcium silicate. This material acts as a bonding agent to hold the rest of the sand together. Most sand-lime bricks will compare favorably with "first common" clay bricks. They are characterized by their straight edges, parallel faces, and nearly white color. Their continued use in

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[4] Circular No. 109.

Northern climates has established their durability under weather conditions, but sand-lime brick is not a refractory material. The industry maintains a national association with which the Bureau coöperates in conducting research work on the subject. Bureau of Standards Technologic Paper No. 85 contains detailed descriptions of the method of manufacture and of several factories. A good sand-lime brick for general purposes should have an absorption of not over 20 per cent., an average compressive strength of not less than 2000 pounds per square inch, and an average modulus of rupture of not less than 450 pounds per square inch.

COLORED WALL PLASTER.[5]

By W. E. Emley and C. F. Faxon.

[ABSTRACT.]

Gypsum wood-fibred plaster is a commercial article made of calcined gypsum, wood fibre, and other ingredients. This wood fibre can be dyed with aniline dyes, to produce any desired color, the dyes being fast to light. By the use of dyed wood fibre, a colored gypsum plaster can be made. After this has been applied to the wall and allowed to set, the surfaces may be scrubbed with soap and water, thereby exposing the colored fibres.

Some very beautiful effects may be produced, not only because of the great variety of colors available, but also by the use of fibres of different sizes, by different proportions of fibre and by different surface treatments.

The finished wall may be made artistic because both the color and texture can be controlled. It is in effect a plaster-wall, and should be treated accordingly. It can, however, be scrubbed with soap and water whenever it gets dirty or the colors become dull.

RECENT MODIFICATIONS IN THE CONSTRUCTION OF PLATINUM RESISTANCE THERMOMETERS.[6]

By T. S. Sligh, Jr.

[ABSTRACT.]

The paper describes some recent modifications in the construction of platinum resistance thermometers which have been found desirable on account of a gain in accuracy, a simplification of construction, or on account of the greater mechanical strength.

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[5] Technologic Paper No. 181.

[6] Scientific Paper No. 407.

All thermometers are of the potential-terminal type, as the use of this type with a potentiometer or a Wheatstone bridge with reversing commutator offers complete elimination of the effects of lead resistance.

Changes in the construction of the strain-free type of thermometer from that described in Bureau of Standards Bulletin No. 6, p. 150, 1909, consist in the sealing of the thermometer tube to prevent condensation of atmospheric moisture in the thermometer at low temperatures, the use of a neater and simpler thermometer head composed of a brass shell with bakelite base and cap, and the use of thermometer leads consisting of a four-strand cable insulated with a double-silk wrapping and a silk braid. Each strand of this cable consists of three No. 28 insulated copper wires twisted together and double-silk covered. The lead terminals are cut and formed from thin sheet copper. This form of thermometer lead possesses sufficient flexibility and is far superior in point of constancy of resistance to the fine-strand lamp-cord leads previously used.

Calorimetric thermometers of the type described in Bureau of Standards Bulletin No. 9, p. 483, 1913, have been found to show a value of the delta (δ) constant in the Callendar difference formula of about $\delta = 1.47$ as against delta value of $\delta = 1.495$ for a strain-free thermometer wound of the same wire. The effect of this difference upon the scale defined by the thermometer in the range 0–100° C. was not sufficiently large to warrant an extended investigation as to the cause of the low value of delta. However, later the commercial type of this thermometer was found to show values of delta as low as $\delta = 1.44$. This fact, together with the desirability of extending the range of the thermometer, led to an investigation which indicated that the low value of delta was due largely to a strained condition of the winding of this type of thermometer.

Strain in the winding may be reduced to a negligible factor by thoroughly annealing the wire before winding the coil, by winding under *very light* tension on a mica core plate not less than 0.5 mm. thick in order to avoid the strain due to bending the wire around sharp corners, by flash-annealing the winding both before and after placing it in the case, and by avoiding pressures on the sheath large enough to strain or deform the winding.

The flash-annealing is accomplished by repeatedly connecting the winding to a voltage sufficiently great to bring the winding to a temperature of approximately 1000° C. before the mica has time to reach its dehydration temperature (700° C.). This annealing is specially valuable after the sheath has been flattened down on the coil.

The thermometer case which is made of german silver tubing 0.75 cm. in diameter by 0.02 cm. thick with the lower end flattened into a sheath for the winding is much more robust and fully as effective in eliminating the effects of thermal conduction down the leads and the stem as was the original case with a metal sheath and a glass stem. The four centimeters of the internal leads immediately above the winding are flattened and placed between thin strips of mica, upon which the sheath is pressed tightly.

The head and external leads are as described above. The drying-head previously used has been found to be unnecessary where the thermometer case is tight and the initial drying has been complete.

A type of heating coil constructed by winding resistance ribbon on a flat strip of mica, insulating by means of thin mica side plates, and enclosing in a flattened copper tube or sheath, has been found to be very convenient for general laboratory use. Because of the small heat capacity and the large heat transfer coefficient of this heating coil it is specially desirable for use in thermostated water baths and for work involving the measurement of heat energy. The coil will transfer to a bath of stirred water about 0.07 watts/cm^2 per degree of difference of temperature between the winding and the water. Thus a coil 3 cm. wide by 17 cm. long by 0.15 cm. thick will transfer 1000 watts of energy to a water bath at 25 C. with a winding temperature of about 140 C.

NATIONAL ELECTRICAL SAFETY CODE.[7]

[ABSTRACT.]

Handbook No. 3 contains a third edition of the National Electrical Safety Code which was previously issued as Circular 54. The new edition is a book of pocket size, and the discussion of the rules has been segregated in a separate volume which will appear later as Handbook No. 4.

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[7] Circular No. 3.

In addition to two introductory sections giving definitions of terms, and rules for the grounding of apparatus and circuits, the code consists of four principal parts, as follows:

1. Rules for the installation of machinery, switchboards, and wiring in central stations and substations.
2. Rules for the construction of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.
3. Rules for the installation of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.
4. Rules for safeguarding employees when working on or near electrical machines or lines.

The rules of Section 9 specify where to attach the ground conductor, how to run it, how to make connections. It limits the permissible resistance of ground connections and restricts the joint use of ground conductors.

Part 1 contains sections covering the general arrangement of stations and of equipment; rotating equipment; storage batteries; transformers, ground detectors, etc.; conductors; fuses, switches, etc.; switchboards; and lightning arresters.

Part 2 contains sections devoted to the following subjects: scope and general requirements; pole lines in general; clearances; classification of circuits according to the grade of construction required; specifications for strength, etc.; supply lines in general; supply lines crossing railways; supply lines crossing signal lines and joint use of poles; signal lines; underground construction. Appendices to this part contain: a map showing the three loading districts; loading data and tables of sags for overhead conductors; data and tables for determining sizes of poles and guys required, pole setting, etc.

Part 3 contains sections dealing with the following items of utilization equipment: scope and general requirements; conductors; fuses, switches, etc.; switchboards and panel-boards; motors; furnaces, batteries, transformers, and lightning arresters; lighting fixtures and signs; portable devices; cars, cranes, and elevators; telephones and signal apparatus.

Part 4 contains operating rules for both employer and employee, with separate sections dealing especially with supply stations, supply lines, and telephone and telegraph lines.

This Code has been developed with the coöperation of all interests concerned, including the different classes of utilities, manufacturers, electrical workers, insurance companies, state and city administrative officials. It has been thoroughly revised for this edition, and nearly all of the rules are acceptable to those who must work under them. They have already been made mandatory in a number of states, and their use, no doubt, will be greatly extended now that the new edition is available. They are being used voluntarily by a large number of utility companies.

SPECIFICATIONS FOR MARINE SEXTANTS.[8]

[ABSTRACT.]

These specifications, incorporating standard practice in design and performance of sextants, are the basis for certificates issued by the Bureau of Standards. They cover the rigidity, durability, convenience of operation, and mechanical perfection of the instrument; range and accuracy of the scales; consistent tolerances for the mirrors, shade glasses, and telescopes; and provisions for adjustment and replacements.

New instruments are expected to conform closely with these specifications or represent improvements. The precision required of old instruments is placed somewhat below that required of new in order that those which are still serviceable and reliable may not be excluded from certification.

British Gas Mantle Industry.—According to a statement to the Board of Trade by the Incandescent Mantle Manufacturers' Association (*Journ. Soc. Chem. Ind., Review*, 1921, xl, 39–40), five factories now exist in Great Britain for the manufacture of thorium nitrate, which is used in the mantles, from Indian monazite sand. The capacity for yearly output of gas mantles is now over 130,000,000. It is estimated that 32,000,000 more tons of coal would be required yearly to produce the same illumination, if flat-flame burners were used instead of gas mantles. An adequate supply of benzene, toluene, and related hydrocarbons for the industries can be obtained only by stripping gas; and such stripped gas can be used as an illuminant only in conjunction with gas mantles.

J. S. H.

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[8] Circular No. 110.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN MUSTARD SEEDS AND SUBSTITUTES: I. CHINESE COLZA (*BRASSICA CAMPESTRIS CHINOLEIFERA* VIEHOEVER).[1]

By Arno Viehoever, Joseph F. Clevenger and Clare Olin Ewing.

[ABSTRACT.]

MATERIAL imported as rape seed and sold as mustard seed was identified as Chinese colza, *Brassica campestris chinoleifera* Viehoever, n. var. The characteristics of the seed have been established, and those which permit the identification and differentiation from true mustard seed have been pointed out. Plants have been grown from the seed, and the characters have been established, especially with reference to their close relationship to the colza group, *Brassica campestris.*

The volatile oil obtained from the material was identified as crotonyl isothiocyanate, which is not a suitable substitute for mustard oil, with respect to condimental, bactericidal, or medicinal value. The fixed oil proved to be of the general composition of the rape oils, and the quantity of the oil present, amounting to more than 40 per cent., characterized the seed as a very valuable oil seed.

On the basis of the general composition of the seed and the character of the volatile oil, it is suggested that the pressed oil cake may well be used as a stock feed.

The leaves are succulent and should be of value as greens.

The plants, which are very vigorous and apparently hardy, seem to offer possibilities as a forage crop. Experiments along this line have been undertaken in coöperation with the Bureau of Plant Industry.

CONDENSED DESCRIPTION OF CHINESE COLZA (*BRASSICA CAMPESTRIS CHINOLEIFERA* VIEHOEVER).

Basal or radical leaves first single, later numerous, arranged in clusters, large glossy green, usually smooth, obovate or round, obovate in general outline, entire or obscurely wavy, variously toothed, sometimes crenate, tapering into a distinct thin petiole, which is more or less margined, showing sometimes a few leaflike lobes.

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* Communicated by the Chief of the Bureau.

[1] Published in *Journal of Agricultural Research,* Vol. 20 (1920), No. 2, p. 117.

Leaves of flowering stem more or less glaucous, clasping, obovate, oblong, or somewhat lanciolate acuminate; leaves of secondary stem not always clasping.

Flowers light yellow, of medium size (generally that of mustard flowers), pedicels averaging well over ½ inch.

Pods rather large and long, tapering into conical beak (0.4 to 0.8 inch long); pod and beak together from 2 to 3 inches long; from 8 to 12 seeds in pod.

Seeds yellow and brown, yellow greatly predominating; somewhat compressed, oval, usually distinct ridge on ventral side, usually smooth brown, slightly reticulated, varying in size (from 1.69 to 2.07 mm.), weighing from 1.4 to 6.4 mgm. (1000 seeds weighed 2.865 gm. and 500 cc. weighed 352 gm.).

Seed Coat.—Epidermis about 5 microns thick; when it is moistened shows no swelling, no polarization of light, or cell structure. Parenchyma almost completely compressed. Sclerenchyma (palisade cells), from 15 to 31 microns high and from 8 to 15 wide, strongly thickened at the base and side, without pigment, inner wall smooth. Pigment layer consists of one row of cells containing pigment only in brown seeds. Protein layer is formed usually by one row of large cells (from 15 to 21 microns high and from 15 to 42 microns wide).

Seed.—Composition averages as follows: Over 40 per cent. fatty oil (colza or rape oil type); about 23 per cent. protein ($N = 6.25$); 11.5 per cent. reducing substances; 4 per cent. crude fibre; 0.5 per cent. by hydrolysis of volatile oil consisting of crotonyl isothiocyanate.

THE CARE OF LEATHER.[2]

By F. P. Veitch, H. P. Holman and R. W. Frey.

[ABSTRACT.]

Directions for the selection of safe, sensible and serviceable boots, shoes, harness, leather belting and other articles, together with detailed advice on the care of leather, are given in Farmers' Bulletin 1183 of the United States Department of Agriculture.

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[2] *U. S. Dept. of Agri., Farmers' Bul. 1183,* issued December, 1920.

It is stated that the general application of the directions given will decrease the nation's shoe bills by from 300,000,000 to. 250,000,000 pairs and double the average period of serviceability of harness and machine belts. Formulas for water-proofing shoes, worked out in the Bureau of Chemistry and found to be the best of several hundred tried, are given.

A BACTERIOLOGICAL STUDY OF CANNED RIPE OLIVES.[3]

By S. A. Koser.

[ABSTRACT.]

In the bacteriological examination of 480 commercial containers of ripe olives, living microörganisms were obtained in practically every instance from samples which were abnormal, as indicated by either a swelled condition of the container or a bad odor. Viable microörganisms were found in a small percentage of normal containers. These were either ærobic, spore-forming bacilli, cocci, or apparently dormant members of the colon group. A study of the organisms encountered in the spoiled samples showed a great diversity of types, among which the colon group predominated.

KRYPTOCYANINES. A NEW SERIES OF PHOTOSENSITIZING DYES.[4]

By E. Q. Adams and H. L. Haller.

[ABSTRACT.]

A NEW type of photosensitizing dye having an absorption maximum near 7000 Å and a sensitization maximum near 7400 Å has been prepared in the Color Laboratory of the Bureau of Chemistry. These dyes are formed by the action of alcoholic alkali and formaldehyde (or chloroform) on the alkyl halides (or other quaternary addition compounds) of sufficiently pure lepidine and its homologs. Dyes of the same or similar type are produced under some circumstances in the absence of formaldehyde or chloroform. The name "kryptocyanine" is suggested for these dyes, the structure of which has been tentatively worked out.

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[3] Published in *Journal of Agricultural Research*, Vol. 20 (1920), No. 5, p. 375.

[4] *J. Am. Chem. Soc.*, 42 (1920), 2661.

THE MAINE SARDINE INDUSTRY.[5]

By F. C. Weber.

[ABSTRACT.]

A SPECIAL study was made of the existing methods of canning sardines, special attention being given to the transportation of the fish from the fishing grounds to the canneries, and methods worked out for the improvement of the pack at the various steps of the packing process.

A chemical and bacteriological study of the food of the sea herring from which the Maine sardine is made showed that two organisms, *Bacillus Walfischrauschbrand* and a bacterium designated as *Bacillus B,* are associated with this food. Ammonia and amines were determined as end products of their growth. The difficulty with "swells," experienced by the packer, has been traced to the presence of these bacteria. Suggestions for the prevention of decomposition of the fish have been made.

Many uses for the unavoidable waste, including the preparation of fish meal for animal feeding purposes, are suggested, as well as ways to eliminate the avoidable waste of edible portions of the fish.

It is believed that by heeding the Bureau's suggestions, the Maine sardine packer may greatly improve his output and compete more successfully with the foreign packer. Some of the suggestions have already been adopted by the sardine industry, with gratifying results.

ORANGE VINEGAR—ITS MANUFACTURE AND COMPOSITION.[6]

By H. D. Poore.

[ABSTRACT.]

THE results of experimental work conducted by the Citrus By-Products Laboratory show that there is no reason why orange vinegar, put up in quart bottles under well-established brands, can not compete with the fancy grades of cider vinegars, which retail in quart bottles at from 80 cents to $1.40 a gallon.

Samples of orange vinegar submitted to jobbers making a

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[5] *U. S. Dept. Agr. Bull. 908,* issued January, 1921.

[6] Published in *J. Ind. Eng. Chem.,* 12 (1920), 1176.

business of handling vinegar have been pronounced as fine as the best grades of their product. The color, odor, and taste are practically the same as those of apple vinegar, no distinguishing characteristic being noted.

OTOBA BUTTER.[7]

By Walter F. Baughman, George S. Jamieson and Dirk H. Brauns.

[ABSTRACT.]

Otoba butter, the fat expressed from *Myristica otoba,* has been used for many years by the South Americans as a medicament for skin diseases of domestic animals. A sample from Colombia, South America, has recently been investigated in the Bureau of Chemistry. When received it had a brown color and a disagreeable odor. It was found to contain 9.3 per cent. of essential oil (obtained by steam distillation) with the following characteristics: Specific gravity at 20°C., 0.89067; specific rotation, $[\alpha]^{20}_{D}$, −32; and refractive index at 20°C., 1.4180. This essential oil appears to be composed of sesquiterpenes. The unsaponifiable constituents other than the essential oil which are present in large amounts are two crystalline isomers, otobite and iso-otobite. The remainder was a very viscous, yellow resin-like mixture which was not further investigated.

Composition of Unsaponifiable Constituents.

Constituent.	Carbon	Hydrogen	Oxygen	Molecular weight	$[\alpha]^{20}_{D}$	Calculated for $C_{20}H_{20}O_4$		
						C	H	O
	Per cent.	*Per cent.*	*Per cent.*			*Per cent.*	*Per cent.*	*Per cent.*
Otobite ...	74.10	6.19	19.71	310	− 35.7	74.05	6.21	19.74
Iso-otobite.	74.29	6.06	19.64	315	+ 5.3			

These otobites did not give the phytosterol tests. When brominated, both gave penta-bromides. The Zeisel method showed that otobite contained one meth-oxy group, and the iso-otobite, none.

Chemical and Physical Characteristics of the Fat.

Specific gravity, at 20°/20° C.	0.9293
Refractive index at 40° C.	1.4710

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[7] Published in *J. Am. Chem. Soc.,* 43 (1921), 199.

Iodin number (Hanus)	54.0
Saponification value	185.0
Melting point (°C.)	34.0
Essential oil (per cent.)	9.3
Unsaponifiable matter (other than essential oil) (per cent.)	20.4
Fatty acids (per cent.)	67.6

Chemical Composition of the Fat.

		Per cent.
Glycerides of	Lauric acid	15.1
	Myristic acid	52.2
	Palmitic acid	0.2
	Oleic acid	3.9
Essential oil		9.3
Unsaponifiable	Otobite Iso-otobite	9.4
	Viscous resin	11.0

Visibility of the Landscape During Rain.—F. W. Preston. (*Nature,* November 11, 1920.)—On a visit to Wales the author "was impressed with the variations in the visibility of the landscape when rain was falling. In the lower valleys a storm which may be sufficient to wet thick clothing through in a few moments may leave the contours of the mountains quite distinct at several miles distance. On the other hand, a mountain drizzle or 'Scotch mist' may render everything invisible at a few yards." Assuming that the atmosphere is perfectly transparent, that the rain-drops are entirely opaque, and that the phenomena of the persistence of vision may be neglected, a simple treatment of the matter is presented which leads to the interesting result that the obscuring power of a storm (the reciprocal of the maximum distance at which objects can be seen through the storm) is directly proportional to the number of drops falling per second on a unit area, and in no way depends on their size. It is also proportional to the coefficient viscosity of the medium in which the drops fall and is inversely proportional to the acceleration of gravity. Thus for two storms exactly alike in all respects, except that one was at the equator and the other at the pole, the obscuring power would be greater at the former place, because there the acceleration due to gravity is less. Objects could be seen at a greater distance through the polar storm. The difference between the obscuring powers of a Scotch mist and of a heavy rain depends upon the vastly greater number of mist droplets sinking across a given horizontal line in a second than is the case with the rain. The author calculates that under his assumptions and taking a rainfall consisting of drops one mm. in diameter and amounting to one cm. per hour, the landscape would be blotted out at a distance of seven km., or 4.5 miles from the observer. G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

WATER-GAS APPARATUS AND CENTRAL DISTRICT COAL AS GENERATOR FUEL.

By William W. Odell.

By reason of the greatly increased cost of the gas oil used to enrich water gas, and the higher costs of coal and labor, many gas companies, especially those having franchises that call for the delivery of gas of a certain quality at a certain price per 1000 feet, are having financial difficulties. Reconstruction of plants to manufacture coal gas instead of water gas is difficult if not economically impossible under present conditions. The situation calls for the use of practical economies and methods. One of these economies is the use of cheaper grades of coal to replace anthracite or coke.

The U. S. Bureau of Mines, in coöperation with the Illinois Geological Survey and the engineering experiment station of the University of Illinois, is investigating the possibilities of substituting Indiana and Illinois coal for coke in water-gas generator sets. The investigation has included a study of present practice in commercial plants, with a view to determining changes needed in equipment, design and operation when burning coal as compared with anthracite or coke. Results of the preliminary studies are presented in Technical Paper 246 of the bureau, entitled, "Water-Gas Apparatus and the Use of Central District Coal as Generator Fuel."

SAYBOLT FUROL VISCOSIMETER.

By E. W. Dean.

As inspection work for the U. S. Shipping Board had impressed on the Bureau of Mines the desirability of defining fuel oil in terms of viscosity rather than gravity, the Bureau secured the coöperation of George M. Saybolt in developing a satisfactory viscosimeter for testing heavy fuel oils. Assistance was also rendered by the Bureau of Standards, and several other organizations interested in fuel testing. The new viscosimeter, which has been named the "Saybolt furol," has been adopted by the U. S. Shipping Board, the Bureau of Mines, and the Committee on Standardization of Petroleum Specifications, as official for testing heavy fuel oils. The instrument has a wide range of applicability in commercial transactions in fuel oil and its use is recommended to buyers and sellers of the more viscous types of residuum products. A report describing the viscosimeter has been issued in mimeographed form.

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* Communicated by the Director.

THIRD SEMI-ANNUAL MOTOR GASOLINE SURVEY.

By N. A. C. Smith.

Surveys made by the Bureau of Mines of motor gasoline marketed in 1915, 1917, and 1919, showed that motor gasoline had become notably less volatile during each two-year period. Semi-annual surveys were then instituted to determine whether this change was continuing. The first of these, in January, 1920, showed little change. The second in July, 1920, indicated a marked decrease in volatility, but this was attributed largely to seasonal variation in quality of gasoline manufactured for summer sale as compared with winter. The third survey, in January, 1921, shows the same volatility, but the lower boiling point and higher end point indicate that a large proportion of gasoline is being made by blending casing-head or natural-gas gasoline with naphtha. Results of the last survey have been published in mimeographed form.

Explosives Regulation.—A history of the administration of the Federal Explosives Act of October 6, 1917, recently terminated by Joint Resolution of Congress, is presented in a recent bulletin (No. 198) of the Bureau of Mines, entitled, "Regulation of explosives in the United States, with special reference to the administration of the Explosives Act of October 6, 1917, by the Bureau of Mines," by C. E. Munroe.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 16, 1921.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 16, 1921.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership, since last report, 7.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

General John J. Pershing was nominated by the Board of Managers to the Institute for honorary membership and the following resolution was unanimously adopted:

> *Resolved,* That the Board of Managers recommend to the Institute the election to Honorary Membership of General John J. Pershing, General of the Armies of the United States, in recognition of his signal success in the use of scientific and technical methods and means in modern warfare.

Mr. Andrew M. Fairlie, Chemical Engineer, of Atlanta, Georgia, was introduced and presented the paper of the evening, entitled "Recent Developments in the Manufacture of Sulphuric Acid." The paper was devoted chiefly to the nitration processes for the manufacture of sulphuric acid. Consideration was given to some of the developments in design and construction of plant as well as developments in operation which have become noteworthy during and since the war. Acid-proof masonry towers, new varieties of tower-packing material, the Mills-Packard water-cooled acid chamber, other recent proposals for removing the heat of the chamber reactions by means of water-cooling, and nitration by means of oxidized ammonia gas were briefly discussed. The subject was illustrated by lantern slides.

The thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 2, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, March 2, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following report was presented for Final Action:

No. 2750: Tate Electrolytic Waterproofing Process. The Howard N. Potts Gold Medal to Mr. Alfred O. Tate, of New York.

The following report was presented for first reading:

No. 2749: Surface Combustion Burner.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 3, 1921. The meeting was called to order at 8 o'clock by Dr. Gellert Alleman.

Mr. C. A. Emerson, Jr., Chief, Engineering Division, Department of Health, Commonwealth of Pennsylvania, Harrisburg, Pa., presented a paper on the "Disposal of Industrial Wastes and Stream Pollution." Consideration was given to the engineering aspects of recent developments in methods of treatment of some of the industrial wastes widely distributed throughout Pennsylvania. The possibilities of the prevention of stream pollution and the recovery of by-products were pointed out. The subject was illustrated by lantern slides.

The paper was discussed, a vote of thanks extended to the speaker and the meeting adjourned.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 10, 1921, at 8 o'clock, with Mr. Benjamin Franklin in the Chair.

Lafayette B. Mendel, Ph.D., Sc.D., Professor of Physiological Chemistry, Yale University, New Haven, Connecticut, presented the paper of the evening, entitled "Chemical Factors in Nutrition." The speaker reviewed the history of the changing conceptions regarding the rôle of digestion in nutrition and indicated how the newer investigations have contributed to the formulation of present-day views regarding what constitutes a food. Reference was also made to some of the current ideas of metabolism, its relation to the chemical composition of the diet, its variations in health and disease and the limitations of our knowledge in regard thereto. The subject was illustrated by lantern slides.

The thanks of the meeting were extended to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, February 24, 1921, at 8 o'clock, with Mr. W. C. L. Eglin in the Chair.

The paper of the evening, entitled "The Economic Aspects of Railway Electrification," was read by Mr. A. H. Armstrong, M.E., Chairman, Electrification Committee of the General Electric Company, Schenectady, New York. After a review of the present condition of the railway service, due largely to the soaring price of fuel and labor, consideration was given to the economic advantages which will result from the universal replacement of the steam engine. An account was given of the development of the electric locomotive and its use on the several railway lines throughout the United States. Attention was also called to its great reliability and low cost of maintenance. The subject was illustrated by lantern slides.

After a discussion the thanks of the meeting were extended to the speaker. Adjourned.

R. B. Owens,
Secretary.

MEMBERSHIP NOTES.

ELECTION TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 9, 1921.)

RESIDENT.

Mr. J. Vincent Huffnagle, 88 Elgin Avenue, Westmont, New Jersey,
Mr. Oscar G. Schrom, 6017 Nassau Street, Philadelphia, Pennsylvania.
Mr. J. Lester Woodbridge, 19th Street and Allegheny Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

Mr. Thomas W. Hicks, 4516 Fremont Avenue, South Minneapolis, Minnesota.
Mr. M. Selga, Manila Observatory, Manila, Philippine Islands.
Mr. J. M. Spitzglass, 2240 Diversey Boulevard, Chicago, Illinois.
Mr. Spencer J. Steinmetz, 31 Evans Road, Brookline, Massachusetts.

CHANGES OF ADDRESS.

Mr. Frederick M. Bennett, 2516 Harlan Street, Philadelphia, Pennsylvania.
Mr. Edwin Frank, care of C. H. Wheeler Manufacturing Company, Lehigh and Sedgley Avenues, Philadelphia, Pennsylvania.
Mr. John W. Hill, Rooms 45-46 Bodmann Building, 621 Main Street, Cincinnati, Ohio.
Mr. S. C. Hollister, Wig, Hollister & Ferguson, Land Title Building, Philadelphia, Pennsylvania.
Mr. James D. Lee, Jr., 5929 Greene Street, Germantown, Philadelphia, Pennsylvania.
Mr. Edward E. Marbaker, 11416 Ashbury Avenue, N. E., Cleveland, Ohio.
Mr. Orin C. Stout, Chillicothe, Barr County, Ohio.
Mr. F. R. Wadleigh, Assistant to President, Tuttle Corporation, 15 Broad Street, New York City, New York.

NECROLOGY.

Daniel Baugh was born near Downingtown, Chester County, Pennsylvania, on October 22, 1836, and died at Palm Beach, Florida, on February 27, 1921. He was educated at a private academy near his home and at the Fremont Seminary in Norristown.

In 1853 he joined his father and brother in the founding of a plant for the manufacture of fertilizers by artificial and chemical means. After two years of experimental and technical investigations the first super-phosphate was placed on the market. The plant has been in continuous operation since that time.

Mr. Baugh was greatly interested in art and the sciences, and for more than twenty-five years was President of the School of Design for Women. He contributed much of his time and wealth to the cause of education, especially in the field of medicine. Mr. Baugh was a member of many clubs and other organizations and his membership in The Franklin Institute dated from May 8, 1874.

Mr. George M. Newhall, Commercial Trust Building, Philadelphia, Pennsylvania.

Mr. H. B. Rosengarten, P. O. Box 1625, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

DALBY, W. E.—Steam Power. 1920.

DENNIS, L. M.—Gas Analysis. 1920.

FALK, G. K.—Chemical Reactions. Their Theory and Mechanism. 1920.

GRAUBAU, A. W.—Geology of the Non-Metallic Deposits. 1920.

HARROW, B.—Eminent Chemists of Our Time. 1920.

HEINEMAN, P. G.—Milk. 1919.

JOHNSON, C. M.—Rapid Methods for the Chemical Analysis of Special Steels. 1920.

LOVETT, W. J.—Applied Naval Architecture. 1920.

LOW, D. A.—Heat Engines. 1920.

MCKAY, G. L., AND C. LARSEN.—Principles and Practice of Butter Making. No date.

MATTHEWS, J. M.—Application of Dyestuffs to Textiles, Paper, Leather, and Other Materials. 1920.

POYNTING, J. H.—Collected Scientific Papers. 1920.

STOCKING, W. A.—Manual of Milk Products. 1919.

UNWIN, W. C.—A Treatise on Hydraulics. 1912.

VANSLYKE, L. L.—Modern Methods of Testing Milk and Milk Products. 1920.

WHITBY, G. S.—Plantation Rubber and the Testing of Rubber. 1920.

GIFTS.

Acheson Graphite Company, Electric Furnaces, Brass Melting, Acheson Electrodes in Use. Niagara Falls, New York, 1920. (From the Company.)

Air Reduction Sales Company, Cutting Cast Iron with Oxacetylene Torch. New York City, New York, 1920. (From the Company.)

Aluminum Company of America, Aluminum Electrical Conductors. Pittsburgh, Pennsylvania, 1920. (From the Company.)

American Institute of Mining and Metallurgical Engineers, Transactions, Vol. lxiii. New York City, New York, 1920. (From the Institute.)

Atmosphere Conditioning Corporation, Bulletin No. 50. Philadelphia, Pennsylvania, 1920. (From the Corporation.)

Bastian Blessing Company, Rego Welding and Cutting Apparatus. Chicago, Illinois, 1920. (From the Company.)

Batterman Truitt Company, Modern Ventilating Apparatus. Philadelphia, Pennsylvania, 1920. (From the Company.)

Boston Gear Works, Standardized Boston Gears. Chicago, Illinois, 1920. (From the Works.)

Brown, A. and F., Company, Power Transmission Machinery. New York City, New York, 1920. (From the Company.)

Bureau of Engineering, Annual Report for the Fiscal Year 1920. Washington, District of Columbia, 1920. (From the Bureau.)

Burton, Griffiths and Company, Ltd., B. S. A. High Speed Steel Milling Cutters, Reamers, and B. S. High Speed Steel Twist Drill. London, 1920. (From the Company.)

Canada Department of Mines, The Production of Iron and Steel. Ottawa, Canada, 1920. (From the Director.)

Carey, The Philip, Company, Catalogue No. 1352. Cincinnati, Ohio, 1920. (From the Company.)

Carpenter, George B., and Company, Catalogue No. 110. Chicago, Illinois, 1920. (From the Company.)

Chicago Engineer Supply Company, Cesco Boiler Tube Cleaners. Chicago, Illinois, 1920. (From the Company.)

Colgate University, Annual Catalogue, 1920–1921. New York City, New York, 1920. (From the University.)

Combination Pump Valve Company, Pump Valves for every Use. Philadelphia, Pennsylvania, 1920. (From the Company.)

Coppus Engineering and Equipment Company, Coppus Centrifugal Turbo Boiler Feed Pump. Worcester, Massachusetts, 1920. (From the Company.)

Cornell University, The President's Report, 1919–1920. Ithaca, New York, 1920. (From the University.)

Crescent Manufacturing Company, Catalogue No. 25. New York City, New York, 1920. (From the Company.)

Cutler Hammer Manufacturing Company, Steel Mill Control and for the Mine. New York City, New York, 1920. (From the Company.)

De La Vergne Machine Company, Municipal Power Plants. New York City, New York, 1920. (From the Company.)

Electric Controller and Manufacturing Company, Bulletin No. 1044. Cleveland, Ohio, 1920. (From the Company.)

Garratt-Callahan Company, Magic Boiler Preservative. Chicago, Illinois, 1920. (From the Company.)

Gas Combustion Company, The Bradshaw Burner. Pittsburgh, Pennsylvania, 1920. (From the Company.)

General Electric Company, Ltd., Switchgear High and Low Tension. London, England, 1920. (From the Company.)

General Radio Company, Bulletins of Electrical and Radio Laboratory Apparatus. Cambridge, Massachusetts, 1920. (From the Company.)

Greenfield Tap and Die Corporation, Catalogues Nos. 40, 42 and 43. Greenfield, Massachusetts, 1920. (From the Corporation.)

Hammett, J. L. Company, Catalogue for Basket Making and Miscellaneous Manual Art Supplies. Cambridge, Massachusetts, 1920. (From the Company.)

Hoover, Owens, Rentschler Company, Poppet Four-Valve and Uniflow Engines. Hamilton, Ohio, 1920. (From the Company.)

Institution of Naval Architects, Transactions for 1920, Vol. lxii. London, England, 1920. (From the Institution.)

Lietz, A., Company, Solar Ephemeris, 1921. San Francisco, California, 1921. (From the Company.)

Link-Belt Company, Book No. 435 and Book No. 352. Chicago, Illinois, 1920. (From the Company.)

Little, Arthur D., Incorporated, The Petroleum Outlook. Cambridge, Massachusetts, 1920. (From the Corporation.)

Liverpool Engineering Society, Transactions, Vol. xl, Forty-fifth Session. Liverpool, England, 1920. (From the Society.)

McAlear Manufacturing Company, Bulletin A, B, C, D, E, and Catalogue No. 25. Chicago, Illinois, 1920. (From the Company.)

Metal and Thermit Corporation, Thermit Insert Rail Weld. New York City, New York, 1920. (From the Corporation.)

Mine and Smelter Supply Company, Bulletin No. 60. New York City, New York, 1920. (From the Company.)

Mississippi State Geological Survey, Bulletin No. 60. Jackson, Mississippi, 1920. (From the Director.)

Mississippi Wire Glass Company, Booklet. New York City, New York, 1920. (From the Company.)

Mount Holyoke College, The Catalogue, 1920–1921. South Hadley, Massachusetts, 1920. (From the College.)

Museu Nacional du Rio De Janeiro, Archives, Vol. xxii. Rio De Janeiro, Brazil, 1919. (From the Museum.)

New Jersey State Agricultural Experiment Station, Fortieth Annual Report for 1919. Trenton, New Jersey, 1920. (From the Station.)

New York Public Service Commission for the First District, Annual Report for 1917. New York City, New York, 1920. (From the Commissioner.)

New York State University, Fifteenth Annual Report of the Director of the State Museum. Albany, New York, 1920. (From the University.)

Northern Engineering Works, Northern Type D. Electric Hoists. Detroit, Michigan, 1920. (From the Works.)

Oersted, J. C., La découverte de l'électromagnétisme faite en 1820, Publication aux frais du trésor pour le comité J. C. Oersted par Absalon Larsen. Copenhagen, Denmark, 1920. (From the Committee.)

Ontario Department of Mines, Twenty-ninth Annual Report for 1920. Toronto, Canada, 1920. (From the Department.)

Peerless Electric Company, Bulletin Nos. 36, 37A, 39 and 200. Warren, Ohio, 1920. (From the Company.)

Pennsylvania Department of Mines, Report for 1918, Part ii, Bituminous. Harrisburg, Pennsylvania, 1920. (From the Department.)

Pennsylvania Forge Company, Die Blocks and Forging Bars. Philadelphia, Pennsylvania, 1920. (From the Company.)

Pneumercator Company, Incorporated, " Primer." New York City, New York, 1920. (From the Company.)

Quigley Furnace Specialties Company, Hytempite in the Gas Plant. New York City, New York, 1920. (From the Company.)

Railway Review Company, The Need of Automatic Train Control. Chicago, Illinois, 1920. (From the Company.)

Reading Iron Company, Reading Wrought Iron Pipe. Reading, Pennsylvania, 1920. (From the Company.)

Ready Tool Company, Catalogue No. 19. Bridgeport, Connecticut, 1920. (From the Company.)

Robinson, Dwight P., Company, Light, Heat, Power, Building with Concrete, Shops. New York City, New York, 1920. (From the Company.)

Royal Manufacturing Company, Clean Clean Through. Rahway, New Jersey, 1920. (From the Company.)

Simms Magneto Company, The Simms Huff Starting and Lighting System. East Orange, New Jersey, 1920. (From the Company.)

Smith College, Catalogue, 1920–1921. Northampton, Massachusetts, 1920. (From the College.)

Smull's Legislative Handbook and Manual of the State of Pennsylvania for 1920. Harrisburg, Pennsylvania. (From the State Librarian.)

South Dakota State Board of Railroad Commissioners, Thirty-first Annual Report for 1920. Madison, South Dakota, 1920. (From the Board.)

Sprague Electric Works, Spraguelets and Bulletin No. 48,961. Philadelphia, Pennsylvania, 1920. (From the Works.)

Stanford University, Twenty-ninth Annual Register, 1919–1920. Stanford University, California, 1920. (From the University.)

Thermoid Rubber Company, Universal Joints and Their Use and Misuse. Trenton, New Jersey, 1920. (From the Company.)

Thomas, R., & Sons Company, Catalogue No. 19. East Liverpool, Ohio, 1920. (From the Company.)

Union Petroleum Company, The Petroleum Problem, Conservation. Philadelphia, Pennsylvania, 1920. (From the Company.)

United States Brewers' Association, Year Book for 1919. New York City, New York, 1920. (From the Association.)

United States Coast and Geodetic Survey, Annual Report, 1920. Washington, District of Columbia. (From the Director.)

United States Navy, Annual Report of the Paymaster General for the Fiscal Year 1920. Washington, District of Columbia, 1920. (From the Paymaster General.)

University of Rochester, Reports of the President and Treasurer, 1919–1920. Rochester, New York, 1920. (From the University.)

Vacuum Oil Company, Bearings and Their Lubrication. New York City, New York, 1920. (From the Company.)

Walworth Manufacturing Company, Walworth Export Catalogue No. 35. Boston, Massachusetts, 1920. (From the Company.)

Washburn Observatory, Publications, Vol. xiii, Part 1. Madison, Wisconsin, 1919. (From the Observatory.)

Washington University, Sixty-fourth Annual Catalogue. St. Louis, Missouri, 1920. (From the University.)

Western Australia Department of Mines, Report for the Year 1919. Perth, 1920. (From the Department.)

Whitlock Coil Pipe Company, Bulletin Nos. 13, 14, 15, 19, 24, 25, 26, 27, 28, 38, 42. Hartford, Connecticut, 1920. (From the Company.)

Whiting Corporation, Catalogue No. 156. Harvey, Illinois, 1920. (From the Corporation.)

Wilson, H. A., Company, Wilco Thermostatic Metal. Newark, New Jersey, 1920. (From the Company.)

Winton Engine Works, Winton Marine Oil Engines. Cleveland, Ohio, 1920. (From the Works.)

Wollensak Optical Company, Lensology and Shutterisms. Rochester, New York, 1920. (From the Company.)

BOOK NOTICES.

"DIE RELATIVITÄTS THEORIE EINSTEIN'S, von Max Born, Berlin; Julius Springer, 1920. 7 + 242 pages, with 128 figures and a portrait of A. Einstein.

The author of this book, issued as Volume iii of the series "Naturwissenschaftliche Monographien und Lehrbücher," is an accomplished theoretical physicist well known to specialists through his original investigations on the relativistically rigid body and of the physical properties of crystalline structures (space-lattices). Unlike most of his writings, thoroughly mathematical and accessible to a few people, the present work gives an easily readable, almost popular presentation not only of Einstein's special and general theories, but—what is more instructive for the beginner—a very sound and attractively written exposition of the physical bases of these theories. In fact, this preparation of the ground occupies as much as two-thirds of the volume. It guides the reader through the rudiments of space and time measurement (Chapter I) and a most happy presentation of the fundamental concepts and laws of classical mechanics (II) to "Newton's World System" (III) and the corresponding relativity principle with the Galilean transformation as its analytical expression. Inertia and centrifugal force find here an able treatment. Chapters IV and V are devoted to the fundamental laws of Optics and of Electrodynamics, respectively, and lead the reader in a masterly way from the rudiments of light theory to the dragging of light by matter and astronomical aberration, and from electro- and magneto-statics to Maxwell's electromagnetism and Lorentz's electron theory.

In due time and connection the Michelson experiment is described, and a good account is given of the contraction hypothesis which had to explain its nil-effect. This carries us at once to Einstein's Special Relativity Principle (VI), a beautiful chapter on the concept of simultaneity, on Einstein's elementary kinematics and the Lorentz transformation, illustrated by Minkowski's graphical representation of the behavior of moving clocks and measuring rods and deepened by a special section on appearance and reality. The addition theorem of velocities and special relativistic mechanics and optics of moving bodies follow, in a readable form, and the chapter closes with a good description of Minkowski's "absolute world" or space-time. Chapter VII, and last, perhaps a little too short, gives, however, an introduction into the General Relativity and gravitation theory which will be very helpful to a large circle of readers. It deals with the principle of equivalence and the insufficiency of euclidean geometry for general purposes, explains the use of Gaussian coördinates (labels) on the intuitive sub-case of a two-dimensional manifold, and, after a critical section on Mathematics and Reality, guides us into the metrics of the four-dimensional, space-time continuum, and the fundamental laws of the new mechanics. A description of the three well-known verifiable predictions of Einstein's new theory, two of which were crowned with success, and a general survey of Einstein's recent cosmological speculations on the one, and atomism on the other, hand (Macrocosmos and Microcosmos), close the chapter.

As an appendix Einstein's biography and a condensed chronological table are given, the latter starting from 300 B. C. (Euclid) and ending with 1879, the year of Einstein's birth.

LUDWIK SILBERSTEIN.

KOLLOIDCHEMIE. Ein Lehrbuch von Richard Zsigmondy. Dritte, vermehrte, und zum Teil umgearbeitete Auflage. Mit einem Beitrag: Bestimmung der inneren Struktur und der Grösse von Kolloidteilchen mittels Röntgenstrahlen; von P. Sherrer. 409 pages, contents, index, seven plates and fifty-eight illustrations in the text, 8vo. Leipzig, Otto Spamer, 1920. In paper, $4.20; bound, $5.00.

Ordinarily the third edition of a standard work would require but formal notice. Some allusion to the fact of the new edition is evidence that the work has met some "long-felt want," that banal expression of authors and reviewers, with notes of such improvements and additions as the authors had kindly set forth for the accommodation of reviewers, who often confine themselves to reading the preface, generally suffices for the report on the book. The present volume deserves more extended treatment. Everything that comes out of Germany is interesting to the thinking people of the other countries. The tragic history of the last six years is in every one's mind, and exclusive of those who were joined with the Teuton, scarcely any great nation is openly friendly. The author of the book feels keenly the situation, and in a postscript to the preface to this edition expresses himself as follows:

"May this edition serve as a slight evidence to co-workers in other lands that the search for truth is still being pursued in Germany with zeal, and that, in spite of sufferings and humiliations that have been accompanied with frightful incidents, we have not ceased to view phenomena objectively, and have endeavored to acknowledge the merits of others. When the search for truth is the object, all accessory conditions must be left to one side. May those who think that this spirit is unworthy of confidence, consider that their own doings and conclusions will be subject to the calmer judgment of posterity. We will stand firmly in the confidence that the spirit of right, of justice and of love of truth will finally win out, and that the spirit of conciliation will eliminate the errors that have been left as a result of a period of great storm."

The general text of the book remains much the same as in former editions. All those who are interested in colloid phenomena are familiar with the author's exhaustive and vivid treatment of the subject. Additions have been made throughout, but in a footnote to the above-quoted postscript to the preface, Doctor Zsigmondy states that though he has zealously sought to secure the data presented in sources outside of Germany, yet since 1914 this has been difficult, and he expresses the desire that he shall be furnished with copies of contributions by co-workers in all parts of the world. It is to be hoped that this request will be heeded.

The most interesting of the new matter in the book is the appendix by Professor Scherrer on the structure and dimensions of colloid particles as determined by the X-ray. The remarkable results obtained by Laue's method applied to crystallized forms, carried out in considerable detail by the Braggs, naturally suggested extension to the formless masses, and it is along this line that Scherrer has worked with great energy and ingenuity. The essay is too long to abstract here, and is necessarily abstruse, but among the results attained is that the number of really amorphous substances is much smaller than heretofore supposed, inasmuch as many presumably amorphous powders have been found to be made up of finely dispersed crystalline masses. Amorphous boron is an instance. The molecular aggregations of liquids are not crystalline masses, and the result of studies show that certain phenomena are common to all liquids; and that, further, certain solids, such as glass and gelatin, exhibit strong analogies to liquids and may be regarded as sub-cooled masses.

The mechanical execution of the book is excellent, the paper being good and the type clear and neat. These are matters of moment nowadays, when so much inferior printing and paper is offered at high price.

HENRY LEFFMANN.

THE MICROSCOPE. ITS DESIGN, CONSTRUCTION AND APPLICATIONS. A SYMPOSIUM AND GENERAL DISCUSSION BY MANY AUTHORITIES. Edited by F. S. Spiers, B.Sc., F. Inst. P. 260 pages and contents, with many plates and illustrations in text, 8vo. London, Charles Griffin & Co.; Philadelphia, J. B. Lippincott Company. $5.00 net.

The numerous papers in this book covering many phases of the science of microscopy, both in theory and applications, are the results of discussions held at three different times. The initial symposium was on January 14, 1920, at the rooms of the Royal Society in London. An adjourned meeting was held on February 24th at Sheffield, and a further meeting in London on April 21st.

Experts in the various phases of the construction and application of the microscope contribute to the symposium, and it is unnecessary to say that the book contains a vast amount of interesting matter. The main participants were the Faraday Society, the Royal Microscopical Society and the Photomicrographic Society, these groups being in coöperation with the Technical Committee of the British Science Guild. After some reference to the state of the art, and reminders of the importance to both Britain and America of so cultivating the practical side that these nations may be independent of all others, the general history of the microscope is taken up. It is shown by a quotation that Seneca knew that curved surfaces will magnify, and it is stated to be probable that the manuscript illuminators of the fifteenth century were familiar with moderate magnifying apparatus. The first illustrated publication which gives definite evidence of the use of a magnifying glass appeared in 1592 at Frankfort, bearing the name of George Hoefnagel. It consisted of a series of plates engraved on copper illustrating common natural objects, but drawn with great skill and minute accuracy. Some of the drawings reveal details that are hardly distinguishable to the unassisted eye. A Dutchman, Zacharias, miscalled Jansen, and his son, made microscopes before the year 1619. In 1665, Hooke published his famous book "Micrographia," in which he described using small drops or globules of glass. A fac-simile of the title page of the book is given.

A good deal of space is given to the subject of metallography, which though comparatively recent in its extensive applications, and in the efforts to construct apparatus for its pursuit, yet is really over a century old, the method having been first used by Widmanstätten in 1808, who polished a specimen of meteoric iron and examined the surface. His work is preserved in the title "Widmanstätten Figures" applied to the phenomenon. The practical application of the microscope to the study of metallic masses is due to Sorby, who began his work in this line in 1864. Years before, however, he had laid the foundation of one of the most important applications of microscopy—petrography—the extensive ramifications of which are now one of the most prominent features of mineralogy and geology.

The book is illustrated by a large number of excellent plates and many illustrations in the text. Necessarily, being made up of the contributions of many persons and of notes of extemporaneous discussions, the subject matter is somewhat disconnected, but the material presented is all of importance and value, and the book constitutes one of the best of recent publications in the field of pure and applied microscopy.

HENRY LEFFMANN.

A TEXT-BOOK OF PRACTICAL CHEMISTRY. By G. F. Hood, M.A. (Oxon.), B.Sc. (Lond.), and J. A. Carpenter, M.A. (Oxon.). xii + 514 pages and index, 162 illustrations, 8vo. Philadelphia, P. Blakiston's Son and Co. Price $5.00 net.

To those whose first descriptions of laboratory manipulations were derived from Morfit's Chemical Manipulations, the contrast with the modern works in this field is sufficiently striking. The introduction of electricity and the employment of vacuum apparatus have notably modified every-day procedures.

The present work is a very comprehensive description of methods in the preparation and testing of chemical compounds, covering both inorganic and organic fields. It is compactly and conveniently printed, and contains a very large amount of information, so that a student who should go through it carefully and conscientiously will acquire a very satisfactory knowledge of the practical procedures in chemistry, and as these procedures are explained in their theoretical relations, such student will have also a good idea of the fundamental principles of the science. Eighty-eight pages are given to physical chemistry, in which important methods are elucidated, among which may be mentioned optical activity, electro-chemistry, spectroscopy and the phase-rule.

HENRY LEFFMANN.

A TEXT-BOOK ON SURVEYING AND LEVELLING. By H. Threlfall, M.Sc. Tech., Engineering Lecturer in the College of Technology, Manchester. 663 pages, illustrations, 12mo. London, Charles Griffin and Company, and Philadelphia, J. B. Lippincott Company, 1920.

The practice of surveying in this country is so different from that taught in England, that it is difficult to review an English work on this subject, and do justice to its author.

In this country, for instance, the chain is rarely used, except by the old-time county surveyor, the modern surveyor making his measurements either with steel tape and band, or in a rough country by the stadia method; the results obtained with the latter being as accurate as chaining, and at an economy of time and labor.

The use of the measuring rod for extreme accuracy, which apparently is stressed by Prof. Threlfall, has been practically abandoned in this country. Greater speed and as high a degree of accuracy is obtained by the use of steel bands, observing connections that reduce the percentage of error to such a minimum that the methods are employed in the measurement of U. S. primary base lines.

The description of the use of the Plane Table would be of little service to an American engineer, as his method and purpose in using this instrument are so radically different from those described by the author.

On the other hand, the chapters treating of "Cuttings and Embankments," and the adjustments for linear errors in a closed polygon survey, without affecting the angular measurements, contain some valuable information.

There is also a very excellent chapter on "Photographic Surveying" and the chapter on "Tacheometry," or as it is commonly called in this country, "Stadia Surveying," is complete and practical.

BENJAMIN FRANKLIN.

LABORATORY MANUAL FOR THE DETECTION OF POISONS. By Wilhelm Autenrieth, University of Freiburg i.B. Authorized translation by William H. Warren, Ph.D. Fifth American edition, 322 pages, contents, index and 25 illustrations, 8vo. Philadelphia, P. Blakiston's Son and Co. Price $3.50.

This work has been so long before the chemical profession that it needs little more than a notice of the appearance of a new edition. It is a translation from the fourth German edition, the same as was used in the preparation of the fourth American edition, inasmuch as a revision of the German work has apparently not yet appeared. There is also a special British edition, in which some subjects not found in the German original were included and are also treated in the American edition. Among these is the vexing question of "normal arsenic." For many years chemists were satisfied that arsenic is not a normal constituent of the human body. As the delicacy of tests increased, however, it became possible to detect extremely minute amounts of the elements, and Gautier, in 1841, asserted that he was able to find traces of arsenic in certain organs of the human body without there being any reason to assume its direct introduction. The subject was extensively examined, but the results given by Kunkel, as quoted in the book before us, are that whatever traces of arsenic occur in human organs they are too small to have any value in toxicologic examinations. It must also be borne in mind that in most cases of arsenic poisoning there is a symptomatology which aids in the diagnosis. It is to be noted that all the claims for the existence of arsenic normally in the body are from French investigators, and are all more than a dozen years old.

The American editor has wisely added a considerable amount of matter on methyl alcohol, now so prominent as a poison. Unfortunately, neither this name nor "wood spirit" appears in the index. Important literature on the subject has been cited, but Gettler's exhaustive investigation, published in *Journal Biol. Chem.*, seems not to have been used.

It is a puzzling question as to how far a translator should incorporate information local to the country for which the translation is intended. The practices of different nations are often very different and users of the book may be misled if the translation is made too close. In the present case, for instance, it is stated that strychnine nitrate is the salt commonly used in medicine, but the American practice gives preference to the sulphate. It is to be regretted that Reinsch's test for arsenic is not included in the list, for it is specially applicable as a preliminary test on stomach contents, vomited matters and other complex organic mistakes. It is, further, a delicate test, and when carefully carried out, reliable.

It seems a pity that the publisher has been put to the expense of printing the structural formulas of many of the alkaloids. These have no value in practical toxicology, which is essentially empiric in its methods.

Henry Leffmann.

An Introduction to Chemical Pharmacology. Pharmacodynamics in Relation to Chemistry. By Hugh McGuigan, Ph.D., M.D., University of Illinois. vii + 407 pages and index, small 8vo. Philadelphia, P. Blakiston's Son and Co. Price $4.00 net.

This work is an effort to bring together the data that bear on the relation between chemical composition and physiologic action. The author's view, as set forth in the preface, is perhaps more optimistic than the facts support, or as the book summarizes them. It is natural that the chemist should hold to the view that the composition of a substance should be the sole cause of its physiologic action, but such an opinion seems at present to be more a matter of faith than of demonstration. Dr. McGuigan holds that it is upon this phase of opinion, namely, reference of all physiologic action to composition, that science is entering. He asserts that the purely physiologic methods, in which changes of blood-pressure, respiration and heart rate are recorded, seem spent, and many are convinced that chemistry now offers the most hopeful method for the solution of many of the problems on pharmacology.

Changes, we are further told, in the functions of the body are due to the chemical reactions between the drugs and the tissues. "Physical changes also result, and it is often difficult to separate the purely physical from the purely chemical." It might be difficult to define exactly what is a physical and what a chemical change. Some distinguished chemists are of the opinion that this is a distinction without a difference.

Turning to the text of the work, it is found to give large space to the chemistry of drugs and to the tests and reactions relating to them. In fact, the proportion of space given to general chemistry is much larger than that devoted to the explanation of the relations between the chemical composition and the physiologic effect. There is a very large amount of information on the structure of the several classes of organic compounds. From an artistic point of view, the reviewer considers that most of the formulas take up too much room.

The author makes a distinction between "catalysts" and "enzyms," stating that the latter are all destroyed at 100°, and many of them at 60°. It seems to be intended that on the difference between enzyms and catalysts is based this difference of action of heat, but as the word "catalyst" is not in the index, and no further statement is given in connection with the section on enzyms, it is not certain upon what Dr. McGuigan bases it. It seems to be an unnecessary distinction, if the author reserves the term "catalyst" for inorganic bodies.

HENRY LEFFMANN.

ELEMENTARY ELECTRICAL ENGINEERING. By Ralph Preston Clarkson, Professor of Engineering, Acadia University, N. S. xvi + 187 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1920. Price, $2.00.

This book is intended for the use of students in Mechanical, Civil and Chemical engineering, also for those who need to acquire a considerable acquaintance with Electrical engineering calculations and machinery in a comparatively short time. The author has developed his purpose with considerable success, and has produced an excellent little text-book if properly supplemented by lectures. The book is so small for the extent attempted to be covered that its faults are greatly emphasized. Often the line is not sharply drawn between informal class talks and the conciseness demanded by a text-book. Too much merely elementary electrical physics is included in the earlier chapters; and many of the illustrations are of the catalogue type and employed irrelevantly. However, many principles of electrical engineering are explained in a style so lucid it is regrettable the author did not attempt a larger text written similar to that of the admirable chapter on the solution of circuits.

WILBUR M. STINE.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 107, A High-speed Engine Pressure Indicator of the Balanced Diaphragm Type, by H. C. Dickinson and F. B. Newell, Bureau of Standards. 15 pages, illustrations, diagrams. Washington, Government Printing Office, 1921. This report describes a pressure-measuring device especially adapted for use in mapping indicator diagrams of high-speed internal-combustion engines. The cards are obtained by a point-to-point method giving the average of a large number of engine cycles. The principle involved is the balancing of the engine cylinder pressure against a measured pressure on the opposite side of a metal diaphragm of negligible stiffness. In its application as an engine indicator the phase of the engine cycle to which a pressure measurement corresponds is selected by a timing device. The report discusses briefly the errors which must be avoided in the development of an indicator for light high-speed engines, where vibration is serious, and outlines the principles underlying the design of this instrument in order to be free of such errors. A detailed description of the instrument and accessories follows, together with operating directions. Specimen indicator diagrams are appended. The indicator has been used successfully at speeds up to 2600 r. p. m., the highest speed engine available for trial. Its sensitivity is approximately that of a standard six-inch dial gauge of the Bourbon tube type.

Report No. 109, Experimental Research on Air Propellers, IV, by W. F. Durand and E. P. Lesley. 11 pages, illustrations, diagrams. Washington, Government Printing Office, 1921. This is a continuation of a report on the same subject published in the Fifth Annual Report. The research was conducted in the aerodynamical laboratory of Leland Stanford Junior University, and the report was prepared under the direction of Dr. W. F. Durand and Prof. E. P. Lesley. The results of investigations made upon numerous propeller models at the request of the Subcommittee on Aerodynamics are given, as well as valuable data to those interested in the design of air propellers. The discussion accompanying the report is necessarily somewhat brief, as it is to be a part of the general report which will include a review of all the propeller investigations that have been conducted at Leland Stanford Junior University.

PUBLICATIONS RECEIVED.

An Introduction to Chemical Pharmacology. Pharmacodynamics in Relation to Chemistry, by Hugh McGuigan, Ph.D., M.D. 418 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son and Company, 1921. Price, $4.00 net.

Laboratory Manual for the Detection of Poisons and Powerful Drugs, by Dr. William Autenrieth. Authorized translation by William H. Warren, Ph.D. Fifth American edition. 342 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1921. Price, $3.50 net.

A Text-book of Practical Chemistry, by G. F. Hood, M.A., B.Sc., and J. A. Carpenter, M.A. 527 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son and Company, 1921. Price, $5.00 net.

U. S. Bureau of Mines: Technical paper 251, Ventilation in Metal Mines. A Preliminary Report, by Daniel Harrington. 44 pages, 8vo. Technical paper 280, Accidents at Metallurgical Works in the United States During the Calendar Year 1919, by William W. Adams. 31 pages, 8vo. Washington, Government Printing Office, 1921.

Canada Department of Mines, Mines Branch: Annual Report on the Mineral Production of Canada During the Calendar Year 1919. 82 pages, 8vo. Preliminary Report on the Mineral Production of Canada During the Calendar Year 1920, prepared by John McLeish, B.A. Ottawa, King's Printer, 1920-1921.

National Advisory Committee for Aeronautics: Technical Notes No. 28. Loads and Calculations of Army Airplanes, by Engineer Stelmachowski. Translated from Technische Berichte, vol. iii, Section 6. 11 pages, 8vo. Technical Notes No. 32. Causes of Cracking of Ignition Cable, by F. B. Silsbee and J. B. Dempsey. 14 pages, plates, 8vo. Technical Notes No. 44. On the Resistance of Spheres and Ellipsoids in Wind Tunnels, by D. P. Riabouchinsky. Translated from Bulletin of the Aerodynamical Institute of Koutchino. 9 pages, diagrams, 8vo. Technical Notes No. 54. The Factors that Determine the Minimum Speed of an Airplane, by F. H. Norton. 9 pages, diagrams, 8vo. Washington, Committee, 1921.

Solutions of Acetylene in Acetone at High Pressures.—RAYMOND R. BUTLER (*Journ. Soc. Chem. Ind., Transactions,* 1921, xl, 25–26) has made a study of such solutions. Under the British regulations, acetylene may be dissolved in acetone in cylinders until a pressure of 15 atmospheres is reached. For each increase in pressure of 1 atmosphere, the solution expands approximately 4.4 per cent. in volume. If a cylinder contains 40 per cent. of its volume of acetone, the solution of acetylene will occupy 65.6 per cent. of the volume of the cylinder when the pressure is 15 atmospheres. The cylinder is ordinarily filled with porous material, which has a porosity of 80 per cent., and therefore contains 20 per cent. of its volume of solid matter. Therefore, the total free space actually present in the charged cylinder is but 14.4 per cent. of its total volume. No evidence was found of the formation of any compound between the acetone and the acetylene.

J. S. H.

New Test for Cobalt.—According to S. A. BRALEY and F. B. HOBART, of the University of Illinois (*Journ. Am. Chem. Soc.,* 1921, xliii, 482–484), dimethylglyoxime always reacts with aqueous solutions of cobalt salts, in the presence of either sodium acetate or ammonia, to produce a brown color. This brown color does not disappear upon the addition of mineral acids, while the color of other metallic glyoximes is discharged by such acids. Therefore, the reaction may be used as a sensitive qualititative test for cobalt in the absence of such interfering substances as copper and iron. If elements, other than nickel, which give colored solutions or precipitates with sodium acetate and dimethylglyoxime, be absent, the brown color of cobalt dimethylglyoxime may be used for the colorimetric determinatoin of cobalt. If both cobalt and nickel be present, the nickel is determined by precipitation with dimethylglyoxime; and the cobalt is determined colorimetrically in the filtrate from this precipitate.

J. S. H.

CURRENT TOPICS.

Some Experiments in Connection with the Injection and Combustion of Fuel-oil in Diesel Engines. Engr. Commander C. J. Hawkes, R. N. (*Northeast Coast Institution of Engineers and Shipbuilders,* November 26, 1920.)—This paper deals with experiments at the Admiralty Engineering Laboratory on the injection and combustion of fuel-oil in the Diesel engine.

With the air-injection system, a definite quantity of fuel-oil is pumped into the fuel-saving casing, and when the valve lifts, compressed air provided by a high-pressure air-compressor blows the oil into the cylinder in a finely divided state.

In the solid-injection system, no air-compressor is required. The fuel pump raises the oil throughout to a comparatively high pressure, and when the fuel valve lifts, the requisite quantity is forced by its own pressure through a number of small holes in the sprayer, being thus split up into a mist.

The experiments with the solid-injection system will be mentioned first, and subsequently some on the air-injection system.

It will not be possible in this abstract to do more than to give an idea of the nature of the experiments and some of Mr. Hawkes's conclusions therefrom.

Experiments on the Solid-injection System.—For the experiments on the solid-injection system, use was made of a single-cylinder, four-stroke engine 14½" by 15", capable of developing 100 B. H. P. at 380 R. P. M.

An investigation was made to ascertain the cause of and the remedy for the sticking of the exhaust valve (the principal part of the remedy consisted in adding a deflector to protect the valve spindle from the rush of exhaust gases); another to determine the effects of the different numbers and sizes of holes in the sprayer. Most of the tests having been made under pressures, powers, and other conditions usual in such cases. It was found that under such conditions the best all-round results were obtained by the use of five 0.016-inch holes per sprayer.

Experiments were made to ascertain the effect of fitting steel plates to the top of the alloy piston, generally with the result of increasing the fuel consumption.

Others to find out whether this was due partly to some of the fuel-oil assuming the spheroidal state on striking the hot piston, thus delaying the vaporization and combustion.

At 4000 pounds per square inch pressure, however, the roller began to leave the cam, and better results were obtained by increasing the spring load up to 850 pounds, but no advantage was gained by increasing it further. Tests were made on the conditions that brought about "jumping" of the valve.

A study was made on the effect of the length of holes in the sprayer, and a comparison between the 0.016-inch and the 0.019-inch ones, at about 100, 90, 75, 50, and 25 B. H. P. He concludes that the proper number, size, and angle of holes in a sprayer depends upon the mean pressure, the viscosity, the mean indicated pressure, and the distance the jets have to penetrate into the combustion chamber; also on the speed of the engine. The determination of the number, size, and angle of the holes for a given engine, however, is largely a question of trial and error.

Many other experiments were made on the solid-injection system which will not be referred to here.

Air-injection System.—A large number of very important tests were also made on the air-injection system, dealing with many important details, and so comprehensive that not only a great deal of valuable information can be obtained from them in regard to details, but also Mr. Hawkes is enabled to compare the two systems as to their advantages, disadvantages and idiosyncrasies.

G. L.

Stenches for Blue Water-gas and Natural Gas. (*Tech. Paper 267, U. S. Bureau of Mines,* by S. V. KATZ and V. C. ALLISON.)—Loss of life and property frequently result from leakage of fuel and illuminating gases, especially the former. The non-enriched water-gas used for fuel purposes alone, and commonly called "blue water-gas" on account of the flame it produces, is especially dangerous, as it contains about one-third its volume of carbon monoxide, and is almost inodorous. Certain German cities require such gas to be always supplied with a stench to give warning of its escape in an unconsumed form. Natural gas has also little odor. Obviously, the stench chosen should be characteristic, essentially disagreeable, and capable of retaining itself in admixture with the gas through all the transportation that this undergoes. Two dozen substances that seem to be applicable to this purpose have been investigated by the authors of the bulletin. Some of these are too expensive for large scale use, others too liable to cause corrosion of pipes, others again not sufficiently disagreeable to serve as a warning. It must also be borne in mind that a very large number of persons have defective sense of smell, and marked odors may be present in their environment and not be detected by them.

Details are given in the bulletin of the methods determining the value of the several stenches and of the results of these determinations. Some stenches containing notable amounts of sulphur may be objectionable on account of the sulphur oxides that will be added to the air by the combustion of the gas containing them. Wide differences were observed in the efficiency of the substances examined. Amyl thioether ($C_5H_{11}S$) gave the highest odor with the smallest concentration, only 0.4 mg. per cubic foot being sufficient to give strong intensity. Judging by market price alone, the two cheapest stenches which impart a strong odor are amyl acetate and nitrobenzene, but both of these are unsatisfactory because the odors are not unpleasant to many persons. Ethyl hydrosulphide (ethyl mercaptan, C_2H_5HS) and pyridin seem to be the only other stenches with highly disagreeable odors that are quoted at prices that seem worthy to be considered for large-scale use. Pyridin is especially suitable, for although the pure article is quoted at $2.50 per gallon, an impure article, which serves as well, can be obtained from the acid washings of light oils. Phenyl isocyanide has an extremely disagreeable odor, and, though not listed as a commercial chemical, can be prepared by comparatively simple and inexpensive methods. Conservative figuring shows that gas can be probably satisfactorily impregnated with it at a cost of less than one cent per thousand cubic feet.

In view of the strong trend to electric supply for lighting and power, with the consequent relegation of gas to heating purposes, and, therefore, the low enrichment of it, the use of some powerful stench seems to be a necessity for the protection of life and property.

H. L.

The Ultra-micrometer; an Application of the Thermionic Valve to the Measurement of Very Small Distances. R. WIDDINGTON. (*Phil. Mag.*, November, 1920.)—In a circuit containing inductance and capacity the frequency of the electrical oscillation natural to such a combination is dependent on the product of the inductance and capacity. If either of these varies, then the frequency varies also. Suppose the capacity is in the form of a condenser consisting of two parallel plates. A change in the distance between these causes a change in capacity and this in turn brings about a change in the frequency of oscillation. The author calculates that, one-thousandth of an inch being the distance separating the plates, a change of one vibration per second will be brought about by altering this distance by two billionths of an inch—and such a change in frequency can actually be detected.

To realize as far as may be the possibilities indicated by theory the following arrangement was devised: An oscillating valve circuit was set up, including the parallel plate condenser in which change in the interval between the plates was to be investigated and also a loud-speaking telephone joined to a three-stage transformer amplifier. This apparatus gave a frequency of about one million per second. To make evident any change in this frequency a second valve circuit was placed near the first. Its frequency could be adjusted by means of a condenser so as to nearly equal that of the first. Thus the telephone was caused to emit a loud, audible note, whose pitch could be studied against the background of another note maintained at a standard pitch. The pitch of the telephone note was tuned to this pitch. Let the distance between the plates in the first circuit change. A change in the pitch of the note coming from the telephone follows, and in consequence there is a difference in the number of beats heard in a second. A careful study showed that in practice altering the interval between the plates by one two-hundred-millionth part of an inch caused a perceptible change in the number of beats per second. The two notes were brought back into unison by moving the pointer in a variable condenser in the second circuit. When the distance between the plates in the first circuit was made to change by a relatively large distance, such as one one-hundred-thousandth of an inch, it was found that shifting the condenser pointer one-tenth of a degree compensated for separating the plates about three ten-millionths of an inch.

The method is so sensitive that the placing of a British penny on a stout bench supporting the apparatus caused a perceptible audible change, because it bent the bench, tilted the supports and changed the distance from one condenser plate to the other. In view of the fact that the wave-length of the shortest waves of visible light is about one sixty-thousandth of an inch it is seen that this new method of linear measurement can determine distances very much smaller than the wave-length of light; indeed, it is applicable to lengths as small as the diameter of an atom.

G. F. S.

New Foods at a Banquet.—The farewell banquet on February 16th tendered to Secretary Meredith by the scientific workers of the Department of Agriculture, was marked by inclusion in the menu of several articles of food that have been made available by the labors of the department. Two of these articles were materials, for the preparation of which patents have been issued to their devisors, but laid open to public use. These are the "perfect bread," the result of studies by Dr. Carl O. Johns and A. J. Fink, being the first food product furnishing a completely balanced ration, and candies made from sweet-potato sirup. The formula for the latter item has been patented by Doctor Gore. Other items of the menu were American roquefort cheese, saratoga chips made from the newly introduced vegetable, dasheen, a new soy-bean sauce developed by Doctor Church and new varieties of grapes, imported under the direction of Doctor Husmann.

H. L.

Cellulose Acetate and Artificial Silk. (*The Chemical Age.*)—Cellulose acetate, from which dope for aeroplanes and airships is made, has proved itself to be of the utmost value in the aircraft industry, and the conception of laying down and completing the works in the stress of war, and the establishment of a new key industry of vital importance in war, with huge potentialities in peace time, was a marvelous achievement; it was due to the genius of Doctors Henry and Camille Dreyfus. Before the war the value of cellulose acetate was appreciated by few in this country, and there was nobody capable of dealing with the enormous demand which the Air Force program created.

The general belief has been that while acetate of cellulose was a perfect raw material for the manufacture of artificial silk, it suffered the serious drawback of being difficult or impossible to dye.

Contrary to this opinion, the British Cellulose Company has proved that, after most exhaustive trials extending over a considerable period, during which the most minute studies and tests both in the technical laboratories and in bulk have been made, the silk can be dyed in a very easy manner. The operation can be carried out by any dyer in this country without special skill or pre-treatment and by direct dyeing with practically all dyes. The basic, the azo, the acid, alizarine, and other dyes can be used successfully, and in each case the resultant dyed silk is fast to light and is washproof.

The dyed silk has been submitted to tests of ten hours under the Quartz lamp—tests which would practically destroy basic dyes on real or artificial silk, and the results have shown that the silk is not affected in any manner. One outstanding characteristic observed in dyeing the silk is that all dyes are directly absorbed without any pre-treatment whatever. Dyes which are insoluble in water, immediately dye British cellulose silk on immersion in the bath.

The action of the dyes in the case of cellulose acetate silk is believed to be a rare chemical affinity and not a physical absorption. Another interesting feature is that the basic dyes which are not fast to light nor washproof, become so when applied to cellulose acetate silk.

Cellulose acetate silk, both dyed and undyed, has a lustre which is excellent, and it possesses a scroop equivalent to that of natural silk. Many and continuous tests in weaving cellulose acetate silk, both dyed and undyed, have been carried out by large manufacturers of silk goods, piece goods, and ribbons, and the reports are of the most satisfactory character. Indeed, these manufacturers have expressed their astonishment at the easy manner in which the product has worked in their textile machinery. Whether they were using it for warp and weft at the same time, or for one of these, or whether they were working in conjunction with natural silk, the results have been excellent. The absence of breakages under trying conditions has commended it highly to the workers.

This feature is due to the great elasticity of cellulose acetate silk. In this respect it even excels natural silk. This feature permits the silk to be woven on looms running at the highest speed.

Plant has also been installed for the manufacture of non-inflammable celluloid, termed "celastoid." This product has all the advantages of celluloid without the great disadvantage of high inflammability. Such a material is of great value to the celluloid trade, where the high price of camphor has seriously restricted the manufacture of celluloid. The day is not far distant when the use of dangerous highly inflammable celluloid will be prohibited.

The marvelous insulating property of cellulose acetate silk or sheeting is a factor that has aroused great interest in the electrical and allied trades, and the long-sought-for non-inflammable accumulator boxes, wind screens, and a multitude of other articles of necessity will shortly be placed on the market.

The Crystal Structure of Ice. D. M. DENNISON. (*Phys. Rev.*, January, 1921.)—Distilled water was frozen in a capillary tube. The tube with the ice was rotated during a ten-hour exposure to X-rays as a result of which a series of twelve lines were obtained. The method was that of A. W. Hull's crystal powder photographs. The interpretation of the results gives an axial ratio of 1.62, while the value furnished by the crystallographer is 1.617. The number of molecules of H_2O per cu. cm. is calculated to be 3.154×10^{22}. The volume of an elementary prism can likewise be derived from the experimental results and is found to equal 0.6478×10^{-22} cu. cm. From these two it follows that in an elementary prism there are 2.04 H_2O molecules. "Ice belongs, then, to one of the two alternate arrangements which inelastic uniform spheres may assume if packed as closely as possible. This is the same form that magnesium atoms take. . . . With increased knowledge of crystal structure these data may furnish information regarding the shape of the molecule of water. With the hexagonal close packed type of lattice each prism contains on the average one molecule. The result calculated above indicates that in ice crystals the molecules of water are of the form $(H_2O)_2$ or H_4O_2." G. F. S.

An Electromagnetic Theory of Gravitation. H. A. WILSON. (*Phys. Rev.*, January, 1921.)—When an electric system is placed in a medium whose specific inductive capacity varies from point to point it experiences a force tending to move it toward parts of the field where that quantity is greater. A like force acts in a field with variable magnetic permeability. The author bases a theory of gravitation on these facts with the assumption that both the specific inductive capacity and the permeability of the ether are modified by the presence of matter and, further, that the dimensions of the body acted on change when it passes from one part of the variable field to another. He is able to show that his theory is consistent with the inverse square law, with the deflection of light by the sun and with the gravitational effect upon the frequency of light emitted by an atom. " It may be said that since matter is certainly partly electrical and since the refractive index of the ether certainly varies near large masses, it seems certain that part, at least, of the observed gravitational forces must be due to an action of the kind considered in this paper, so that it is satisfactory to find that it is possible to explain the whole attraction by means of this kind of action."

G. F. S.

The Charge on the Atomic Nucleus and the Law of Force. J. CHADWICK. (*Phil. Mag.*, December, 1920.)—" The theory of the nuclear constitution of the atom, put forward by Sir Ernest Rutherford in 1911, has been confirmed by evidence gathered from such various sources that it now forms the foundation on which the development of atomic physics is based. On this theory the positive charge associated with an atom is concentrated on a massive nucleus of small dimensions, surrounded by a distribution of electrons extending over a distance comparable with the diameter of the atom, as usually understood.

" The physical and chemical properties of an element are determined by the charge on the nucleus, for this fixes the number and arrangement of the external electrons, on which these properties mainly depend. The mass of the nucleus influences the arrangement of the electrons only to a very small degree. The nuclear charge is thus the fundamental constant of the atom and the question of its actual magnitude of great importance for the development of atomic theory."

As the consequences and implications of Rutherford's theory became understood attempts were made to connect the nuclear charge with other atomic constants. " van den Broek suggested that the nuclear charge might be equal to the atomic number of the element, *i.e.*, the number of the element when all the elements are arranged in order of increasing atomic weight." The palmary significance of the atomic number in this connection was brought forward by the brilliant young British physicist, Moseley, whose untimely death at Gallipoli was the greatest single loss to science inflicted by German aggression. He showed that the X-ray spectra of the elements was dependent on the square of a number which became greater by one when passage was made from one element to the element of next higher atomic weight. " On the nuclear theory of atomic structure this characteristic number must be closely connected with the charge on the nucleus, and Moseley concluded that the number gave in fundamental units the actual value of this charge. This is one of the most important generalizations in modern physics, and gives a starting-point for the development of the external structure of the atom." The only direct method of measuring the charge on the nucleus is by studying the single scattering of alpha particles. When a pencil of these falls on a thin sheet of matter, the number of the scattered particles falling per second on a unit area of screen at a known distance and angle with the pencil is connected with the number of particles per second in the pencil by a formula in which every quantity is either a known constant or a measurable quantity except the nuclear charge of the scattering atoms. This charge can therefore be calculated from the formula, when the results of experiment are inserted in it.

The direct as well as the scattered alpha particles were counted by the scintillations they produced upon the same zinc sulphide screen. If there were thirty scattered particles per minute, there would be about 20,000 direct particles in the same time. To count this large number a rotating disk with a slit was interposed in the path of the pencil before it reached the screen, so that only a known fraction of the particles could pass. Thus the number to be observed was made so small that it could readily be counted.

Experiments were made for three metals, platinum, silver and copper. In all cases the particles counted numbered some thousands. N means the number by which the fundamental charge of electricity, the charge of the electron, must be multiplied in order to get the nuclear charge of an atom of the metal.

Metal.	N.	Atomic Number of Metal.
Platinum	77.4	78
Silver	46.3	47
Copper	29.3	29

The atomic number of the metal is derived from its X-ray spectra, while N comes from the experiment. The agreement is striking and Moseley's conclusion is confirmed in a remarkable way. An examination of further experimental data leads to the conclusion that the inverse square law holds true in the region of investigation, *i.e.*, within one hundred-billionth of a centimeter from the nucleus.

G. F. S.

Lime Nitrogen.—The claim has been made that lime nitrogen or commercial calcium cyanamide produces injuries of the skin and of the respiratory tract, acts as a poison, and gives rise to a disease with characteristic symptoms—"lime nitrogen disease." SIEBNER (*Chemiker Zeitung,* 1920, xliv, 369–370, 382–383) has made an elaborate study of the subject, and draws the following conclusions: The injuries to the skin are due to free caustic lime which occurs in the cyanamide dust; the injuries to the respiratory tract are exactly the same as those produced by any dust. Calcium cyanamide is not a poison; the amount required to kill a dog is 0.23 gram; a rabbit, 1.4 gram; and a man approximately 40 to 50 grams; the effect of small doses is not cumulative. Most other chemicals which are used as fertilizers, are more toxic, and have a cumulative effect. The lime nitrogen disease appears only if the individual imbibes alcoholic liquors while exposed to cyanamide dust or shortly thereafter. Therefore calcium cyanamide may be used with perfect safety as a fertilizer. The only precautions necessary are those usually taken in handling materials which may yield an alkaline dust. Certain beverages may not be drunk while the workman is exposed to the dust.

J. S. H.

Chemical Evidence of Fatigue.—ERNEST L. SCOTT and A. BAIRD HASTINGS (*Public Health Reports,* 1920, xxxv, 2445–2462) have made elaborate analyses of the urine of resting men, and of men engaged in work of varying degrees of severity. Among their findings is the fact that the absolute quantity of free or unconjugated phenols excreted in the urine was increased slightly by moderate work, and greatly by strenuous labor. Hence the amount of free phenols excreted in this manner may be a factor in severe fatigue.

J. S. H.

Aniline Vapors in Factory Air.—MIRIAM STEWART ISZARD, of the University of Pennsylvania (*Journal of Industrial Hygiene,* 1920, ii, 259–266) has found that aniline vapor is present in the atmosphere in more or less toxic concentration during the dropping of the reducer in the manufacture of aniline, and during the emptying of the phenylglycine dryers in the manufacture of indigo.

However, the workmen are constantly moving about, and do not continuously breathe air with a high aniline content. Air at the floor level contains more aniline than does air at the respiration level.

J. S. H.

Trithiocarbonates and Perthiocarbonates.—According to ERNEST WICKMAN YEOMAN (*Jour. Chem. Soc.,* 1921, 119, 38–54), trithiocarbonates are salts of the acid H_2CS_3, and perthiocarbonates are salts of the acid H_2CS_4, thus sodium trithiocarbonate is Na_2CS_3, and sodium perthiocarbonate is Na_2CS_4. A trithiocarbonate may be obtained by the reaction of the hydrosulphide (sulphydrate) of a metal with carbon disulphide, a perthiocarbonate by the reaction of the disulphide or polysulphide of a metal with carbon disulphide. In the preparation of the sodium, potassium, and ammonium salts, absolute alcohol is used as the solvent; both alcohol and water have been used as solvents in the preparation of the alkaline earth salts (barium, calcium, strontium, and magnesium). Free trithiocarbonic acid apparently is soluble in water, while free perthiocarbonic acid is an insoluble red oil. Aqueous solutions of trithiocarbonates are red, those of perthiocarbonates yellow in color. One molecule of trithiocarbonate is able to combine with one atom of sulphur to form one molecule of perthiocarbonate.

J. S. H.

Spontaneous Ignition of Fire Engine Hose While in Use.—This phenomenon is described by A. H. GILL, of the Massachusetts Institute of Technology (*Jour. Ind. and Eng. Chem.*, 1921, xiii, 168). The rubber hose was provided with two jackets of heavy cotton fabric; a new section, 50 feet in length and 2½ inches in diameter, was used in a test; cold river water was pumped through it at the rate of approximately 250 gallons per minute. The vibration produced in the hose by the pump, caused severe chafing of the cotton jackets, and thereby generated great heat; finally the hose took fire between the cotton jackets; and both jackets were burned through on an area 2 inches long by 1⅛ inches wide. The same result was obtained in several tests, using different types of fire engines and different makes of standard, high-grade hose. In some tests the cotton jackets became charred in approximately fifteen minutes.

J. S. H.

On the Closure of Small Cavities in Rocks Exposed to High Pressures. J. JOLY. (*Phil. Mag.*, December, 1920.)—The specimens of rock examined were in the form of spheres composed of two hemispheres with a common plane surface. In one of these a small hemispherical cavity was centrally ground, or a cavity was provided by laying a steel washer between the two hemispheres. The pressure was got by using a hydraulic press. The temperature was that of the room and some of the tests lasted for months. It was clearly shown " that in thirty tons on the plunger, that is, 38.70 tons or 88,717 pounds per square inch, we have a pressure which is certainly sufficient to close cavities in granite, basalt, obsidian, or limestone."

G. F. S.

Fat Content of Butter.—The technic of the Babcock test for the determination of the fat content of milk or cream has been modified by NELSON W. HEPBURN (*Cornell University Agricultural Experiment Station Memoir 37*, 663–690 (1920)) so that this test may be used for the determination of the fat content of butter.

J. S. H.

A Series of Flights Made with a Free Helicopter. E. OEHMICHEN. (*Comptes Rendus*, February 14, 1921.)—The helicopter had two propellers of diameter 6.4 metres, which revolved in opposite directions. A stabilizing balloon containing hydrogen was rigidly attached to the chassis of wood. This sustained about 20 per cent. of the total weight of 336 kg., leaving 255 kg. to be lifted by the screws which were driven by a 25-horsepower motor of old type. In the month of January, 1921, Mr. Oehmichen made several flights on board this aircraft. He went up only to a height of 3 metres above the ground, having a certain distrust of parts of the apparatus, and carrying no parachute. He reports an absence of pitching in the vertical plane containing the axes of the two screws, while there was considerable rolling. There was a remarkable stability in altitude. Landings without rebound were made when there was no wind.

The author lays stress on the profile of the screws which he planned to resemble the outlines of the wings of moths observed in motion by a stroboscopic method.

The last series of flights were made in the presence of an officer formally designated to be a witness.

G. F. S.

The Problem of Soaring Flight. E. H. HANKIN, Chemical Examiner to Government, Agra, India. (*Proc. Cambridge Phil. Soc.*, Michaelmas Term, 1920.)—Two kinds of soaring flight are shown by birds, flying-fishes and dragon-flies. In slow flight speeds of from 11 to 22 miles per hour prevail, while in rapid flight the speeds range from 33 miles per hour in the case of dragon-flies to 45 miles per hour for vultures. In the slow soaring flight of birds and fishes the tips of the wings are at a higher level than the body, while they are either flat or below the body in rapid soaring flight. As a rule, sunshine must be present for slow soaring flight to be possible, while wind is indispensable for rapid soaring flight.

F. Handley Page remarks: " Doctor Hankin's discovery of the soaring flight of dragon-flies and flying-fishes affords a means of more closely investigating the phenomena of soaring. Observation of birds soaring at 2000 or 3000 feet is difficult compared with the observation of insect flight at a few yards' distance."

Cranes in a flock while in soaring flight keep their relative distances with great exactitude. " They resemble a number of dead birds pinned on a blue wall." This " furnishes a clear proof that the energy involved does not come from any chance or irregular currents of air." There remain two possible causes of such regular flight, *viz.,* unobserved wing motions or some condition that is uniform through wide stretches of the air. Both dragon-flies and fishes retard their flight by adjusting parts of their bodies so as to act as brakes. This seems to rule out undiscovered wing motions as the cause, for, were flight due to such motions, it would appear probable that the speed of flight would be regulated by change in the wing motion and not by a braking adjustment. Moreover, an albatross cannot soar in calm weather near sea level. This it should be able to do, were its soaring dependent on imperceptible wing motions.

Lateral gusts of wind are not the cause of soaring as is shown by the position of the wings which is such that in some cases the thrust of the gust would force the flying organism downward and not upward. Ascending air currents are ruled out as a cause since inland soaring birds avoid them so long as the sun shines. There is some reason to hold that the turbulence of the air may be a factor in soaring flight, but the burden of the evidence is against it. A soaring dragon-fly may be seen gliding in the midst of a group of flapping flies. "What form of preëxisting air movement can be imagined that propels the soaring dragon-fly and yet has no effect on the flapping dragon-fly, though the latter is of lighter weight and loading?"

Having demolished all suggested explanations the author concludes "that soaring flight is inexplicable in the light of existing knowledge," and suggests that experimental investigations be undertaken, since observation alone has failed to furnish the solution of the enigma.

In India the boys play with a puttung, a kite made of paper and bamboo. In a proper wind this flies stably at the top of a vertical string. In this particular, as well as in others, it shows itself akin to the soaring of birds and suggests itself as a promising beginning for an experimental attack upon the problem.

G. F. S.

F. W. ASTON and G. P. THOMSON announce, in *Nature*, February 24, 1921, that their **experiments with positive rays** show lithium to be composed of two isotopes having the atomic weights 6 and 7, respectively. The former preponderates. The relative proportions of the two correspond to the atomic weight of lithium, 6.96.

G. F. S.

Efficiency in Industry. (*Nature*, February 24, 1921.)—The *Daily Mail* of London recently organized an exhibition for the purpose of emphasizing the advantages of applying scientific principles and results to industry. On the historical side the University of London presented the development of the thermionic valve from the lamps of 1887 made with internal plates by J. A. Fleming to study the Edison effect up to the most recent type of valve. There was also on exhibit apparatus used by Sir William Ramsay in his study of the rare gases as well as electrical apparatus employed by Clerk Maxwell.

A wireless set was shown, weighing 20 pounds only, yet capable of receiving messages from continental stations. Chance Brothers exhibited "Crookes" glass for protecting the eyes. This absorbs the ultra-violet part of the spectrum while allowing the visible spectrum to pass. Various devices were shown by which colors can be matched in artificial light.

The range of the exhibition was much wider than would be inferred from the exhibits just cited. The interest manifested is indicative of the growing appreciation in Great Britain of the importance of science to national welfare in peace as well as in war.

G. F. S.

Readers who are interested in the **Principle of Relativity** and who have perhaps already read the essay on this subject to which the *Scientific American* awarded its prize should not neglect to read the issue of *Nature* dated February 17, 1921. By far the larger part of the number is devoted to fourteen papers all dealing with relativity. Among the authors are EINSTEIN, the protagonist of the principle, SIR OLIVER LODGE, SIR FRANK DYSON, NORMAN CAMPBELL, J. H. JEANS and A. S. EDDINGTON. H. A. LORENTZ represents Holland in the symposium, while C. E. ST. JOHN, from the Mount Wilson Observatory, is the sole American contributor. It is interesting to note that DOROTHY WRINCH is one of the joint authors of the article on "The Relation Between Geometry and Einstein's Theory of Relativity." The history and the experimental verification of the new and revolutionary principle are discussed as well as its physical and metaphysical aspects. No French author contributes to this group of papers, and in the bibliography at the end of the collection there seem to be but three references to publications in the French language, and of these one was written by the great Dutch physicist, Lorentz. Have the physicists of France been so dedicated to the defence of their country that they have found no time for the elaboration of the principle, or is this an illustration of the failure of the maxim "Scientia non scit patriam"?

G. F. S.

Magnetic Susceptibility of Low Order. E. WILSON. (*Electrician,* March 11, 1921.)—Three lectures on this subject were given before the Institution of Electrical Engineers. Though the high values of the susceptibilities of ferromagnetic substances usually fixes attention upon this small group, it is none the less true that the much more numerous group of substances possessing small susceptibility, either positive or negative, is well worth considering as well from the practical as from the theoretical point of view. The practical aspect of these lectures is their discussion of the separation of minerals by recourse to their different susceptibilities. Thus the deposit producing monazite contains zircon, which is non-magnetic, and ilminite which has a higher susceptibility than the third constituent, monazite. A rather weak field will separate the ilminite from the other two, while the subsequent application of a stronger field will separate the monazite from the zircon. In order to design magnetic separators the magnetic properties of the constituent minerals must be measured. Hence the first lecture discusses methods of determining the susceptibility, the magnetometer, P. Curie's torsion balance and another type of balance in which the lecturer has replaced torsion by electromagnetic control.

It is found that heat treatment causes marked change in susceptibility. The value of this quantity for chalybite is made larger by heating, while in the cases of chrome iron ore and horneblende the opposite effect is produced. Further, the quantitative results of heat treatment depend upon the state of division and on the access of air. Copper has a negative susceptibility, while its salts show a positive value. Just the opposite is true of magnesium. For more than half a century it has been known that salts with positive susceptibility have a higher value when hydrated than when anhydrous, and this in spite of water's having a negative value itself.

Magnetic separation is now practiced on a large scale. In 1914, 2,200,000 tons of ore were thus dealt with in Norway, in 1917 in Sweden 2,500,000 tons, and in New York 1,200,000 tons in 1916. This is in addition to any separation of wolfram from tinstone ores and of monazite for use in gas mantles.

This subject has a further interest from its relation to magnetic surveys where the susceptibility of rocks has to be reckoned with. When the United States Government was considering a canal through Nicaragua the direction in which the compass pointed on the lake of that name was greatly influenced by the magnetism of a dominating mountain, and in the Boer War the disastrous defeat at Spion Kop was in part due to the confusion of incorrect maps in which directions were modified by the effect of magnetized land masses upon the magnetic needle.

G. F. S.

Sodium Amide.—This compound has been prepared by J. M. McGee, of the University of California (*Journ. of the Am. Chem. Soc.*, 1921, xliii, 586–591), by the action of anhydrous ammonia on pure metallic sodium in the presence of freshly platinized platinum gauze which served as a catalyst. The amide is a white crystalline solid, melting at 208° C. Metallic platinum catalyzes the decomposition of the amide into sodium imide and sodium nitride; ammonia gas is evolved; and the platinum is dissolved at the same time.

J. S. H.

A comparison of the atomic weights of terrestrial and meteoric nickel has been made by Gregory P. Baxter and Leon W. Parsons, of Harvard University (*Journ. Am. Chem. Soc.*, 1921, xliii, 507–518). The atomic weight was obtained by determination of the ratio of nickelous oxide to metallic nickel. The reduction of the oxide to the metal was carried out in an atmosphere of hydrogen at a temperature of 600° to 900° C. Terrestrial nickel was found to have an atomic weight of 58.70, meteoric nickel an atomic weight of 58.68. This difference lies within the experimental error.

J. S. H.

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METEOROLOGICAL ACOUSTICS.*

BY
W. J. HUMPHREYS, C.E., Ph.D.
Professor of Meteorological Physics, U. S. Weather Bureau.

CHAPTER I.

METEOROLOGICAL EFFECTS ON SOUND.

Introduction.

METEOROLOGICAL acoustics is concerned with every sound of a distinctly meteorological origin, such as the humming of telegraph wires, the "roaring of the mountain," the rumbling of thunder, and the like; and with every effect meteorological conditions have on the travel, distribution, and audibility of sound. In short, it treats of meteorological sounds and of meteorological effects on sound.

Nature of Sound.—The term "sound," as used in the science of acoustics, means either an external disturbance or a sense impression. In the more restricted field of meteorological acoustics, it has only the former of these meanings; the sensation being referred to merely as evidence of the presence and nature of a disturbance in the external medium.

Now, everyone knows: (*a*) by observation, that a tuning fork, bell, violin string, and the like, produce sound only when vibrating;

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* Communicated by Dr. E. D. Ball, Assistant Secretary of Agriculture.

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(*b*) by observation, that the hammer is seen to strike, the gun go off, the lightning flash, and innumerable other abrupt causes of sound to occur, before the sound itself is heard, and that this time interval increases with the distance of the observer; (*c*) by experiment, that the sound of a bell, say, mounted on an acoustical insulator within an air pump receiver grows fainter and fainter to extinction as the exhaustion of the receiver is progressively increased.

From these three facts it is obvious that objective sound, or sound in its physical aspect, consists of traveling disturbances of some kind in a material medium. If this medium is the atmosphere (or any other fluid) it is further obvious that the disturbances in question consist of compressions and rarefactions, for the atmosphere has no tendency to recover from distortion of any kind save that of volume alone—no tendency to recover from twist or bend, but a resistance to change of volume that increases with the ratio of that change to the initial volume.

Seeing Sound.—Since sound consists of condensations and rarefactions of the atmosphere traveling outward from the source, and since light is unequally refracted by air of different density, it would seem possible to see, and perhaps even to photograph, the front of a sound pulse. And this has, indeed, often been realized. The outermost sound shell, produced by the firing of a cannon, for instance, has repeatedly been seen sweeping across the sky, and over clouds, like a narrow fleeting shadow. Similarly the initial condensation wave caused by an electric spark has given numerous beautiful and instructive photographs, of which Fig. 1, from Doctor Foley's remarkable collection,[1] showing both the primary wave and its reflection from a flat surface, is an excellent example.

Velocity of Sound.

Velocity of Sound in Still Air.—As stated above, many simple observations show that sound travels through the air with moderate velocity—faster than a mile a minute, and slower than a mile a second. Just what this velocity is might be determined by careful experiment over a large range of temperatures, pressures, humidities, and other factors, and its relation to each empirically determined. But while this has been done to some extent, the collection of an adequate amount of such data would require long and tedious work and the results in the end would be only empirical and not rational. Hence it seems desirable to logically derive equations that show the exact and necessary relation of the velocity of sound to each of the several factors upon which it depends.

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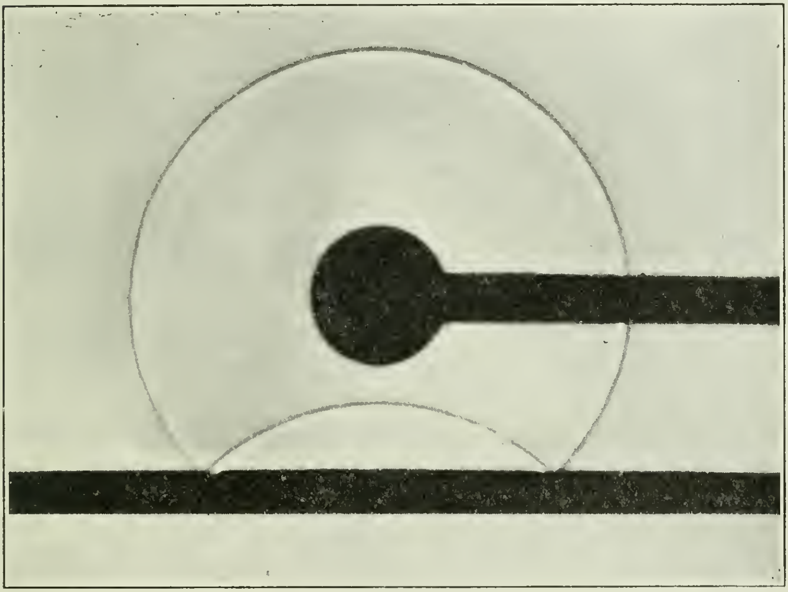
[1] *Phys. Rev.*, 35, p. 373, 1912.

The following method of computing sound velocity is essentially that of Rankine.[2] It may not be so mathematically elegant as the "velocity potential" method, used by Lord Rayleigh,[3] for instance, but it has the great advantage of revealing, rather than concealing, the physical processes involved.

FIG. 1.



Photograph of sound waves—incident and reflected. (A. L. Foley).

Consider an ordinary sound wave (great explosions which result in additions to the atmosphere, and hence require a modified treatment, are excluded) at some distance from its origin, traveling through the atmosphere. As above explained, this disturbance must consist of longitudinal motions of the air particles in the line of travel of the sound, resulting in alternate compressions and rarefactions. This follows from the fact that the atmosphere is elastic only to changes of volume and not to twists or bends. Furthermore, it is clear that these sound excursions of the air particles are small—not even leaves visibly quiver as any ordinary sound passes—and the pressure changes comparatively slight, too slight indeed to be felt.

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[2] *Phil. Trans.*, 160, p. 277, 1870.

[3] "Theory of Sound," ii, p. 15.

Clearly an atmospheric wave of any form, harmonic or otherwise, can be made to progress unchanged through air at any given speed by applying to each particle a proper external force, directed along the line of travel, in addition to the internal force already acting on it.

Let the external force be X per square centimetre in the direction of propagation, that is, per square centimetre of a plane wave front over which, of course, all particles are in the same vibration phase, and hence subject to exactly equal forces; and let X vary in such manner from phase to phase as to keep the form of the wave unchanged and to give it a uniform velocity v. To further simplify the problem, consider an imaginary tube of unit cross section, parallel to the line of propagation and extending through the wave front slightly into the undisturbed region on one side and more or less into the disturbed region on the other. Let this tube be fixed in position, and let the atmosphere flow past it exactly opposite in direction to that of the sound propagation. That is, let the sound waves or that arbitrary portion of a single one, within the tube, though continuously affecting new material, be absolutely fixed in position and condition.

What, under these conditions, are the relations between the forces involved, internal and external, and the deductions therefrom?

Since the quantity and condition of the air within the tube is constant it is obvious that its momentum is also constant, and also, under the given conditions, wholly along the line of propagation. Hence the momentum entering the front of the tube during a given interval, one second say, is equal to the momentum leaving it during the same interval. This momentum *per second* consists of two parts, *a,* the mass entering, or leaving, per second, times its velocity, and, *b,* the pressure upon this mass at the place of entrance or exit, respectively—force is equal to mass times acceleration, which is equal to momentum produced per second in the direction of the force.

Let, now, P be the pressure in the undisturbed atmosphere, and hence at the front end of the tube; $P \pm p$ the pressure at the rear end of the tube (p being either positive or negative, owing to whether this end of the tube is in the compression or rarefaction portion, respectively, of the wave); v the velocity of entry of air of density ρ into the tube; $v \mp u$, and ρ_1 the velocity and density, respectively, of the air as it leaves the tube; and X the assumed sustaining external pressure, constant at each particular phase, and thus constant at the exit end of the tube.

Hence, the momentum entering the tube of unit cross section per second is, if m is the mass

$$mv + P$$

Similarly, the momentum leaving the tube per second is, since the mass within the tube cannot change,

$$m(v \mp u) + P \pm p + X$$

But the two momenta are equal, therefore

$$mu = \rho vu = p \pm X$$

If, now, v is so chosen that

$$\rho v = p/u, X = o$$

and the sound moves on without the aid of any external force with the velocity

$$v = p/\rho u \qquad (1)$$

As above explained,

$$\rho_1 (v \mp u) = \rho v$$

and, if the air remains isothermal,

$$(P \pm p)/\rho_1 = P/\rho$$

Hence, neglecting pu,

$$u = pv/P$$

and, substituting in (1),

$$v = \sqrt{\frac{P}{\rho}} \qquad \text{(Newton)}$$

Or, if the compressional changes take place adiabatically,

$$ku = pv/P$$

in which k is the ratio of the specific heat of the air involved at constant pressure to its specific heat at constant volume, and

$$v = \sqrt{\frac{kP}{\rho}} \qquad \text{(Laplace)}$$

Whether the velocity of sound is in accordance with Newton's equation, or Laplace's, or has, indeed, some distinctly intermediate value (it cannot be outside these theoretical extremes) can, of course, be tested by direct experiment. But here, too, theory is a great help in that it shows[4] the impossibility of a velocity appreciably different from one or the other of the extremes. The non-mathematical form of this reasoning (Stokes gives both) is substantially as follows:

Let an airtight, frictionless, piston oscillate so slowly in a cylinder with thermally conducting walls that the temperature of the enclosed air remains constant. Clearly, then, at each given position of the piston the pressure is the same during expansion as during compression, and the process is without net loss, or gain, of energy. Similarly, if the reciprocal motion of the piston is so rapid that no heat is lost during compression, nor gained during expansion, the pressure, though different from its former value, is again constant for each given position of the piston, and hence the total external work zero per cycle.

If, however, the speed of the piston is such that some heat is passed, but not enough to maintain a constant temperature, the pressure at each point will be greater during compression than during expansion, and the process can be maintained only at the expense of external work. Under these conditions, therefore, the sound would be damped out far more rapidly than is the case in nature.

Actually, sound waves are so fleeting (only those of the baser tones require more than a hundredth of a second to pass) that the slight pressure changes they produce are all but absolutely adiabatic. Hence, to an extremely close approximation,

$$v = \sqrt{\frac{kP}{\rho}} = \sqrt{\frac{1.40\ P}{\rho}} \qquad (2$$

It should be noted here that since neither u, p, nor ρ_1, the only factors affected by either the amplitude or frequency of the vibrating air, enter into equation (2), therefore the velocity of sound is independent alike of both loudness and pitch—the same for all sounds of whatever origin.

Relation of the Air to Sound Velocity.—From equation (2) it is likewise clear that all meteorological changes that alter the value of k, or the ratio of P to ρ, or both, affect also the velocity of sound; and that it is independent of every other such change.

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[4] Stokes, *Phil. Mag.*, 1, p. 305, 1851.

Changes in pressure, therefore, do not alter the velocity of sound. They obviously do not affect the value of k, and, by proportionately varying ρ, leave the ratio of P to ρ constant. On the other hand, variations in the temperature do affect the velocity of sound. In fact, this velocity is directly proportional to the square root of the absolute temperature, T, as is obvious from the fact that when P and k are constant (k constant implies same composition), ρ is inversely proportional to T. Similarly, changes in the absolute humidity also affect the velocity of sound, since they slightly alter the value of k.

The value of k for dry air is 1.40, very closely. Its value for water vapor is not accurately known for ordinary out-door temperatures, but appears to be 1.30 roughly. Presumably, therefore, in nature

$$k = 1.40 - 0.1\, e/P$$

approximately, in which P is the total atmospheric pressure and e that portion of it due to water vapor.

In terms of the reading of the barometer

$$P = (B - .378\, w)\, g\, \delta$$

in which B is the reduced total height of the barometer, w the reduced height due to the water vapor, g and δ the standard gravity acceleration, and mercury density, respectively.

Finally, if ρ_0 is the density of dry air at 0° C. and when the reduced height of the barometer is 760 mm., then

$$\rho = \rho_0 \frac{(B - .378\, w)}{760\, (1 + at)}$$

in which a is the coefficient of gas expansion per degree Centigrade at 0° C., and t the temperature, as read on the Centigrade scale.

On substituting these several values in the equation for the velocity of sound it appears that, in terms of centimetres per second,

$$= \sqrt{\frac{76\, g\, B\, \delta\, (1 + at)\, (1.40 - 0.1\, w/B)}{\rho_0\, (B - 0.378\, w)}}\,.$$

For dry air at 0° C. this reduces to

$$v = \sqrt{\frac{76\, g\, \delta\, (1.40)}{\rho_0}} = \sqrt{\frac{76 \times 980.665 \times 13.5951 \times 1.40}{0.0012930}}\,,$$

or 331.23 metres per second, which is in close agreement with observations.

The effect of dust, smoke, fog, or any other such foreign substance in the atmosphere, on the velocity of sound is not well known. Presumably, however, the values of both k and ρ, and through them the velocity in question, are altered by all such things. But as the aggregate mass of any such substance is invariably quite small in comparison to that of the atmosphere in which it floats, and since it plays the rôle of a gas to only a limited extent, its effect on this velocity must always be minute, and for most purposes entirely negligible.

Doppler Effect.—Many, if not most of us, have often noticed the change in the pitch of a locomotive whistle, or bell, as the train passed rapidly by us; and also the similar change in pitch of a bell, or other sounding object, as we were carried rapidly past it. This phenomenon, known as the Doppler effect, and dependent on the finite velocity of sound, is easily explained.

Let v be the sound velocity; n the vibration frequency, λ the wave-length, and u the velocity of the sounding body towards, or from, the stationary hearer. If u is zero,

$$\lambda = \frac{v}{n}, \text{ and } n = \frac{v}{\lambda}.$$

If the sounding object is approaching the hearer the resulting wave-length λ_1 and frequency n_1 clearly are given by the relations

$$\lambda_1 = \frac{v-u}{n} = \frac{v}{n_1},$$

and

$$n_1 = \frac{nv}{v-u}.$$

Similarly, if the sounding object is receding from the observer,

$$\lambda_2 = \frac{v+u}{n} = \frac{v}{n_2},$$

and

$$n_2 = \frac{nv}{v+u}$$

Hence

$$n : n_1 : n_2 = 1 : \frac{v}{v-u} : \frac{v}{v+u}.$$

That is, the pitch is highest when the sounding object is approaching, and lowest when it is receding.

If, then, the sounding body were on a train, say, making 47 miles per hour, the pitch, as perceived by a person at rest near the track, would drop approximately from *G* (approaching) to *F* (receding) on the musical scale.

If, however, the hearer is moving with the velocity w and the sounding object is at rest, on approaching the body

$$n_1 = \frac{v + w}{\lambda},$$

and on leaving it,

$$n_2 = \frac{v - w}{\lambda}.$$

Hence, in this case

$$n : n_1 : n_2 = v : v + w : v - w$$

If both object and hearer are in motion the expressions for the pitch ratios are only a little more complex—no new principle is involved.

Sound Perception in the Inverse Order of Sound Production.—Another interesting consequence of the moderate velocity of sound propagation is the occasional perception of sounds in the inverse order of their production. This is especially noticeable in the case of high velocity cannon shells passing close by or over one from a considerable distance. Such projectiles often have double the velocity of sound. Hence the first thing heard is the whine of the shell, then its explosion, perhaps, and last of all the firing of the cannon; or, the explosion may be heard last, if far to the rear. All this is obvious when it is recalled that the shell is continuously producing sound far in advance of the initial wave-front from the cannon.

It is also interesting to note that when the source moves faster than sound, as do cannon shells, the wave-front envelop is a cone whose vertex is at the source, and whose angular opening α is given by the equation

$$\sin \frac{\alpha}{2} = v / s,$$

in which v and s are the velocities of sound and of the shell, respectively.

Velocity of Intense Sounds.—Whenever a sound is produced by a violent explosion, such as by the firing of a cannon, the blast itself drives through the air and gives to the sound a velocity which at first, that is, so long as X in the general velocity equation is real and positive, is in excess of that which applies when X is zero.

This excess velocity, however, occurs only relatively near the source of the sound, and rapidly decreases with distance from that source. That is, the external force X is soon reduced to a negligible quantity, after which the velocity becomes constant with the value appropriate to $X = 0$.

Sound Reflection.

Reflection by a Rigid Surface.—As above explained, all sounds in the atmosphere are propagated in the form of successive compressions and rarefactions. If, therefore, these air-waves should impinge normally on a wall of stone, or other dense material, it is obvious that they could not pass on unaltered. If the wall is absolutely unyielding, a condition solid and liquid boundaries more or less approach with respect to slight variations of atmospheric pressure, evidently the adjacent molecules cannot oscillate in the line of propagation. The pressure actions then of the wall on the atmosphere are precisely the same as they would be if it and not the air were vibrating with the given period and amplitude. Hence sound-waves incident on an absolutely rigid wall are wholly reflected, and in such a manner that the surface of this wall is a place of minimum (zero) motion—the incident and the reflected wave having always exactly the same phase at the boundary.

Reflection at a Free Surface.—The effect on sound of a medium of the opposite rigidity extreme, that is, infinitely yielding, such as empty space, is also interesting, though not realizable in the case of the atmosphere. Here the incident compression tends to drive the boundary molecules of the first medium away; if, however, they are restrained from flying off, as is the free end of a vibrating rope, say, or the surface of a liquid, this restraint must be of the nature of a tension. In this way the flux of incident energy is reversed in direction—the waves are reflected. Furthermore, since change of pressure is impossible at a free boundary, the incident waves always have exactly opposite phases at the boundary reflecting surface.

Reflection at an Air Interface.—Let the boundary be between masses of air at the same pressure, but of unequal density owing to difference in temperature, or humidity, or both. This case is of especial importance since it includes the problems of internal atmospheric reflections, and of reflections from fogs and clouds.

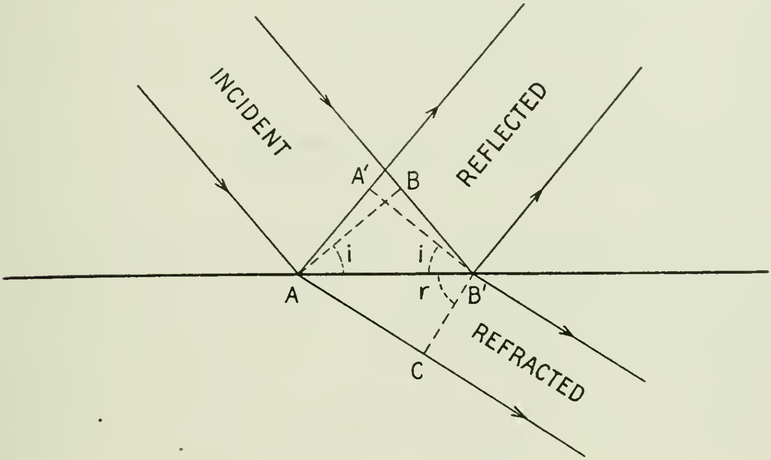
Here, too, as in so many other acoustical problems, the most general treatment is given in Lord Rayleigh's "Theory of Sound."

But the physical significance of each step in this elegant analysis is, perhaps, not easy to visualise. Hence a more obvious course of reasoning will be followed, based on Fresnel's theory of the reflection of polarized light.[5]

If none of the energy of the incident sound waves is transformed into heat at the boundary (and there is no evidence of any such transformation) clearly all of it must be contained jointly in the reflected and the refracted waves.

The laws of the reflection and refraction of sound in still media are the same as those of light. They are given below, but assumed here for convenience.

FIG. 2.



Reflection and refraction of sound.

Let, then, the incident, reflected, and refracted waves be as indicated in Fig. 2; let their amplitudes be *a, b,* and *c,* respectively; let the velocity in the first medium be v, and in the second v'; and let the densities of these media be ρ and ρ', respectively. Then, since the energy in the incident wave is divided between the reflected and the refracted waves without loss, and in each case is proportional to the volume affected, obviously, and to the square of the respective amplitudes as immediately explained below,

$$v \rho a^2 = v \rho b^2 + v' \rho' c^2 \cos r / \cos i$$

in which i is the angle of incidence and r the angle of refraction.

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[5] Fresnel, "Oeuvres," i, pp. 649–653; also Preston, "Theory of Light."

To show, as just assumed, that sound energy is proportional to the square of the amplitude, let f be the restorative, or elastic, force; a the amplitude (extreme displacement of a particle from its position of rest) and w the work of displacement. Now, f is proportional to the compression, that is, to the displacement, x, say. Hence,

$$dw = f\,dx$$

but

$$f = kx,$$

k being a constant, and

$$w = k\int_0^a x\,dx = \frac{k}{2}a^2.$$

Now, $v/v' = \sin i/\sin r$; hence,

$$\rho\,(a^2 - b^2)\sin 2i = \rho'\,c^2 \sin 2r.$$

Also, as above explained

$$(\rho'/\rho)^{1/2} = v/v' = \sin i/\sin r.$$

Therefore

$$a^2 - b^2 = c^2 \tan i \cot r.$$

Furthermore, if there is no slipping between the media at their interface, and it seems impossible that there can be to an appreciable extent, then the algebraic sum of a and b must equal c, or algebraically

$$a + b = c.$$

Hence,

$$a - b = c \tan i \cot r$$

$$b = -a\,\frac{\sin(i-r)}{\sin(i+r)} = -a\,\frac{\left\{(\rho'/\rho)^{1/2} - \cos i/\cos r\right\}}{(\rho'/\rho)^{1/2} + \cos i/\cos r}$$

and

$$c = \frac{2a \cos i \sin r}{\sin(i+r)} = \frac{2a\cos i}{(\rho'/\rho)^{1/2}\cos r + \cos i}$$

If, then, sound waves in a clear atmosphere, say, should impinge normally on a fog bank, or a cloud, in which the density of the air at the same pressure is one per cent. less—a possible ratio owing to differences in temperature and humidity—the energies in the incident, reflected, and transmitted (refracted) waves will have to each other the following ratios, approximately:

$$v\rho a^2 : v\rho b^2 : v'\rho' c^2 = 160{,}000 : 1 : 159{,}999.$$

In making this calculation the small correction due to differences between the specific heats of the two masses was neglected.

If the angle of incidence is not zero as just assumed, but of considerable size, the reflection obviously is greater, but still small for any angle up to nearly 90°. If, for instance, $i = 80°$ and $\rho'/\rho = 99/100$, as above assumed,

$$v \rho a^2 : v \rho b^2 = 100 : 1,$$

roughly. Clearly, then, reflection from fogs and clouds, or at any sharp boundary of sufficient size (greater than wave-length dimensions) between masses of air at the same pressure but of unequal density, varies from a very small value at normal incidence up to total reflection at

$$i = \sin^{-1} (\rho'/\rho)^{\frac{1}{2}}$$

If, as above, $\rho'/\rho = 99/100$,

$$i = 84° \ 15'$$

nearly.

Hence a small number of successive total reflections—not likely to occur, though conceivable—might greatly change the direction of the sound.

If the change in density is gradual through a distance of many wave-lengths—if the medium has no definite boundary—reflection is practically absent, as the equations show. For instance, there can be no reflection of sound from the gradually attenuating upper layers of the atmosphere, as demonstrated by Lord Rayleigh.[6] The energy is maintained through increase of amplitude with decrease of density, except as reduced, as it all finally is, by viscosity, to heat.

Laws of Sound Reflection.—By careful experiment it has been determined that sound is reflected according to exactly the same laws as those that apply to light, namely:

1. The normal at any point of the reflected surface and the directions of incidence and of reflection at the foot of this normal all lie in a common plane.

2. If the reflecting surface is flat and its every diameter large in comparison with the wave-length, the reflection is regular; that is, the angle of reflection (angle between the direction of reflection and the normal to the surface at the point of reflection) is equal to the angle of incidence.

3. Surfaces with less than wave-length diameters do not regularly reflect sound, but merely scatter or diffuse it.

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[6] *Phil. Mag.*, 39, p. 173, 1890.

Echo.—It is well known that in the neighborhood of a flat, vertical wall of some size a loudly spoken word, or brief sentence, often is twice intelligibly heard; the first time as coming straight from the speaker, and the second as if coming from some invisible person in the direction of the wall. This latter sound is the familiar echo (nymph of the poets who pined away until only her voice was left) due to reflection by the wall of the incident condensations and rarefactions in the atmosphere. Parallel walls facing each other, the walls of a canyon, for instance, and separated a few hundred feet, may so reflect and re-reflect the same sound as to cause it to be distinctly heard again and again, through a long fading series. If the reflecting wall is quite irregular, or, especially, if there are walls of various shapes and distances on all sides, the multiplicity of echoes becomes jumbled into a continuous, unintelligible reverberation, a phenomenon most pronounced, perhaps, in certain caves—and auditoriums.

There are of course many natural phenomena due to echo, or sound reflection. Some of the more interesting are: (*a*) the discrete single echo; (*b*) the discrete multiple echo; (*c*) the overlapping multiple echo—reverberation; (*d*) the diffuse echo; due to scattering of the sound by many relatively small objects; (*e*) the harmonic echo; due to the greater scattering of an overtone than of the fundamental by small objects—the scattering of sound, like that of light, being inversely proportional to the wave-length; (*f*) the musical echo; due to reflection from, or scattering by, a series of objects, such as palings or stairsteps, spaced at uniformly increasing distances from the source.

Obviously a single sound impulse such as the crack of a whip, a clap of the hand, and the like, in front of a flight of steps, or just beyond and a little to one side of a row of palings, will be scattered by the successive steps, or palings, respectively, in a series of regularly spaced similar pulses. Hence the " echo " thus produced of any sound pulse is a musical note, whose pitch depends not on the parent sound, but on the spacing of the palings or width of stair treads, as the case may be, and position of the observer.

If s is the spacing of the pickets, or distance from centre of one to the centre of the next, along the path of propagation of the incident sound; and if the origin of the parent sound impulse is nearly in line with the row of pickets, then the distance between the sound impulses, or wave-length l, due to any few successive pickets, is given by the equation

$$l = s\ (1 + \cos \theta)$$

in which θ is the angle, at the pickets in question, between the origin and observer.

An observer therefore at the source, which, as above explained, is beyond the row of pickets and a little to one side, hears a distinctly musical echo of each sharp sound pulse; since at his place the value of cos θ is very nearly the same, unity, for all the pickets, and hence the pitch substantially constant. If, however, the observer is off from the middle of a long straight row of palings, and the source of the impulse is located as before, cos θ will vary from nearly -1 to nearly $+1$, and the echo heard sweep down from the inaudible through a considerable range of the shriller notes.

Sound Refraction.

Sound Refraction in Still Air of Uniform Temperature.—The direction of propagation of sound is abruptly changed whenever it passes obliquely from one to another mass of air at the same pressure but of different density. This is owing to the fact that the velocity depends on the density, as above explained.

If both masses are quiet and equally humid, the velocity of propagation is inversely proportional to the square root of the density. If then i is the angle of incidence in the air whose density is ρ and r the angle of refraction in the air whose density is ρ', the change in direction, as indicated in Fig. 2, is the difference between $\imath$ and the corresponding value of r as given by the equation

$$\sin r = \sin i\ (\rho/\rho')^{1/2}$$

The laws of refraction in this case are identical with those of light, namely:

1. The normal, at any point of the refracting surface and the directions of incidence and of refraction at the foot of this normal all lie in a common plane.

2. The sine of the angle of refraction (angle between the direction of refraction and the normal to the surface at the point of refraction) is to the sine of the angle of incidence as the velocity in the refracting medium is to the velocity in the incident medium; or inversely as the square roots of the densities of the re-

spective media, or directly as the square roots of their absolute temperatures.

Spread of Sound.—Since the velocity of sound in an atmosphere of homogeneous composition is, as previously explained, directly proportional to the square root of the absolute temperature, and since the atmosphere, when at rest, frequently is horizontally stratified with respect to temperature, it follows that sound cannot always spread in precisely the same manner.

Special cases are interesting:

(*a*) Temperature uniform, air quiet and of constant composition. Under these conditions, which, however, never exist, sound would spread uniformly in every direction.

(*b*) Temperature decreasing uniformly with elevation, air quiet and of constant composition. These conditions often are approximately fulfilled through a considerable depth of the atmosphere. They evidently give an oblate ellipsoidal sound shell, with the shorter axis, axis of rotation, vertical. If the origin is on a horizontal surface, the wave front tends to incline upward, owing to the greater velocity in the lowest and warmest air, and hence, the sound to become faint, or even lost, at points on this surface.

(*c*) Temperature increasing upwards (temperature inversion), air quiet and of constant composition—conditions that obtain on a typical frost night.

Let the surface be an indefinite plane, such as the surface of a large frozen lake, and let the temperature be 0° C. at the surface and increase rapidly with elevation to a maximum of 6° C. at, say, 20 meters elevation, and let a sound be produced near the surface.

The velocity of sound, since it varies as the square root of the absolute temperature, will therefore be about 1/100 greater at the top of this inversion layer (layer through which temperature increases with elevation) than at the surface. Hence total reflection will occur for all sound leaving the source between the angles i and $\frac{\pi}{2}$ to the vertical; i being determined by the equation

$$\sin i = \frac{100}{101} \sin 90^\circ ,$$

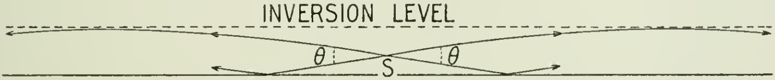
from which $i = 82^\circ$, about.

Hence the whole volume of sound leaving the source S, Fig. 3, within a horizontal toroidal wedge of angle θ (16° in this case) is confined, by refraction above and reflection below, to the surface layer of 20 metres depth. At times this inversion layer is much shallower, but whatever its thickness it is, acoustically, a "speaking disk" in which the intensity of sound is inversely proportional, roughly, to the first power only of the distance. This explains why sounds often carry surprisingly far on still, clear nights.

As a further illustration of this phenomenon let the temperature inversion occur over a river whose banks are free of trees and steep, or canyon-like. Here not only the vertically spreading sound is constrained to a shallow layer, as above explained, but also the horizontally spreading portion is roughly confined to the course of the river by reflection from the banks. That is, the river is one wall of a gigantic "speaking tube" through which sounds occasionally are heard at amazing distances.

(*d*) Temperature rapidly decreasing upward for a few metres, air quiet and of constant composition. Under these unstable conditions sounds travel appreciably faster near the surface than at some distance above it. Hence, sounds originating within or but little above this relatively high temperature surface layer may pass entirely over one's head, even as close as 100 metres to the source, owing to the greater velocities of the lower portions of the sound waves, in proportion to the square roots of the absolute temperatures, and the consequent upward inclination and propagation of these portions of the wave fronts.

FIG. 3.



Sound confined to an inversion layer.

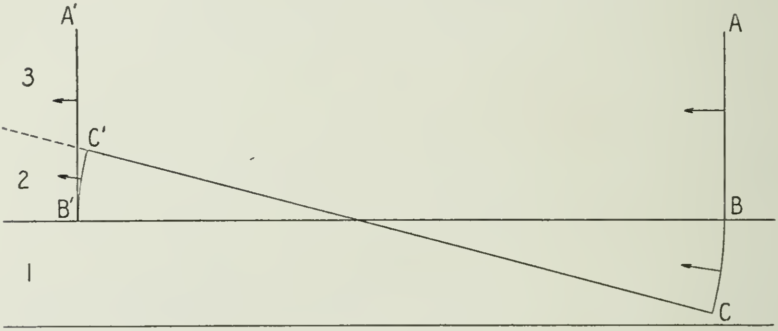
Under the given conditions in the lower air and with an approximately constant temperature through the next layer above, a sound front may be shaped substantially as shown at *ABC*, Fig. 4, and if so it must later develop into the front *A′B′C′*. Owing to refraction *CC′* will not be quite straight, but may be so drawn to represent the general results.

Clearly, then, under the given conditions a person in region 1 will hear only a faint sound, if any at all; at 2 he will hear two identical sounds, probably more or less out of phase, one from the direction of the actual source as given by the undistorted wave front *A′B′*, and the other apparently from some point more or less below the actual source, as indicated by the front *B′C′*. At 3 only one sound is heard, namely, the undisturbed original, and, of course, in its true direction.

The phenomena here described are identical with those of the inferior optical mirage, and are due to the same meteorological conditions. They constitute, therefore, the *inferior acoustical mirage*. Indeed a series of sounding objects arranged vertically might, in position 2, if one were equipped with a suitable sound-pointer, be heard both right side up and upside down.

(*e*) Temperature uniform throughout a shallow layer, then increasing with elevation over several meters to a uniform higher temperature above, air quiet and of constant composition—conditions identical with those that give the superior optical mirage.

Fig. 4.



Inferior acoustical mirage.

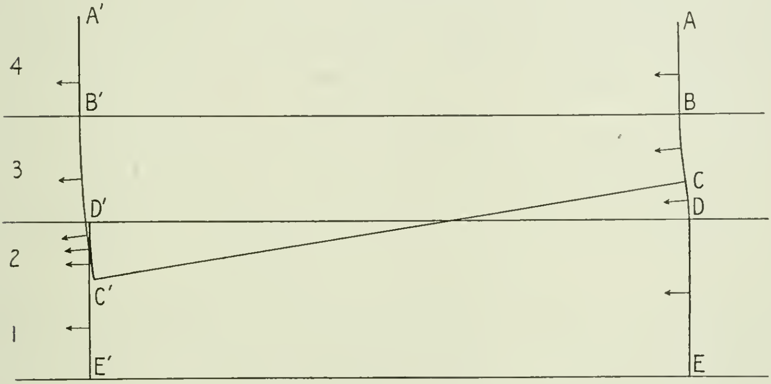
The necessary acoustical consequences of this assumed, and sometimes actual, temperature distribution, may be easily inferred by the aid of Fig. 5. After the sound whose origin is at only a moderate elevation, has traveled for some distance its wave fronts have some such shape as that indicated by *ABCDE,* in the figure, owing to the relation of sound velocity to temperature, as explained above. Farther on this front obviously transforms into *A′B′C′D′E′*, of the figure, from which it appears that: In position 1 only a single sound is heard, and in the direction of the source; in position 2, three identical sounds are possible, one in the correct direction, another apparently from a slightly higher point, and inverted if, as explained under *d,* that be possible, and a third, not inverted, apparently from a still higher point; in position

3, a single sound, apparently from a point distinctly above the true source and, finally, in position 4, also a single sound and again, as in position 1, in the direction of the source.

Since these phenomena are closely analogous to those of the superior optical mirage, and have identical causes, it is suggested that they be called the *superior acoustical mirage.*

Sound Refraction by Straightaway Winds.—Everyone knows, of course, that, in general, winds do not prevent sounds from being heard. Obviously, however, the vibrating portions of the air are carried along with the wind, or, rather, are a portion of it. Clearly, then, the effect of a known wind on the path of a sound ray can be computed with all desired accuracy. Thus, following Barton [7] substantially:

FIG. 5.



Superior acoustical mirage.

Let *AB,* Fig. 6, be the boundary between two horizontal layers of air; let the wind velocity in the lower layer be u_1, and that of the upper u_2, both in the same direction, and $u_2 > u_1$; let θ_1 and θ_2 be the inclinations of the wave fronts to the horizontal in the lower and upper layers, respectively; let ϕ_1 and ϕ_2 be the corresponding angles between the sound paths in the two layers and the vertical, and let the velocity v of sound in still air be independent of altitude—true, on the average, to about one part in a hundred between bottom and top of the lowest kilometer, and correspondingly nearer true in this region for less depths.

Draw *CB'* at right angles to the wave front *AC,* or along a sound path for still air of uniform temperature and composition, and let $B'B$ have such value that $B'B/CB' = u_1/v$. Then CB is the actual sound path in the lower layer.

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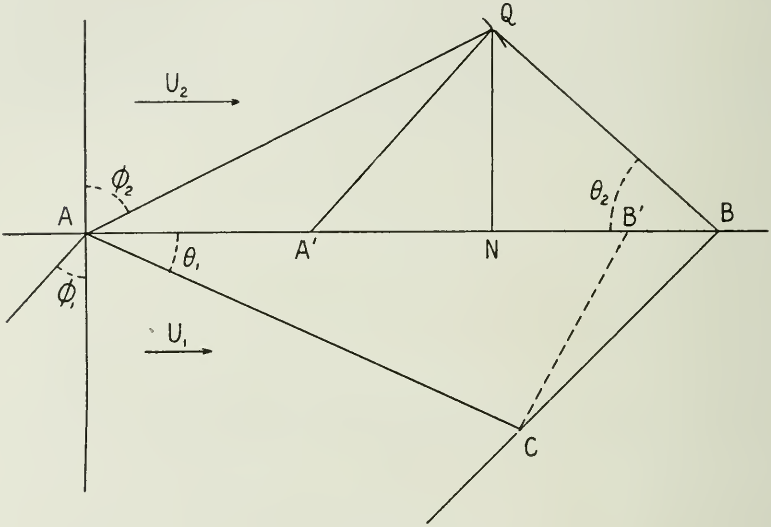
[7] "Text-book of Sound," Macmillan, 1908, pp. 99–106.

To find the wave front in the upper layer resulting from the front AC in the lower, draw $AA' = B'\,Bu_2/u_1$, describe about A_1 a circle whose radius $A'Q = CB'$, and draw BQ tangent to this circle. This tangent BQ is the wave front desired. From the figure

FIG. 6.



Sound refraction by wind.

$$\operatorname{cosec} QBA' = \frac{BA'}{A'Q} = \frac{B'A - AA' + B'B}{CB'} .$$

Hence,

$$\operatorname{cosec} \theta_2 = \operatorname{cosec} \theta_1 - \frac{u_2 - u_1}{v} ,$$

and, for any layer whatever,

$$\operatorname{cosec} \theta = \operatorname{cosec} \theta_1 - \frac{u - u_1}{v} ,$$

or

$$v/\sin\theta + u = v/\sin\theta_1 + u_1,$$

in which θ and u apply to the layer in question.

Clearly, then, since the limiting value of the cosecant of an angle is unity, any pair of values of θ_1 and $u - u_1$, which makes cosec θ in the above equation less than unity provides a case of total reflection.

Obviously, the actual path of a sound ray can be traced through the various layers when their speeds and directions of motion, temperatures, and other acoustical factors, are all given. Thus, from the figure, in which QN is perpendicular to AB, it is evident that

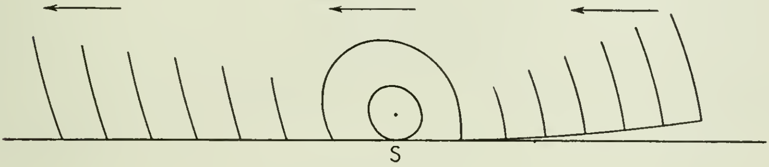
$$\frac{AN}{QN}=\frac{A'N}{QN}+\frac{AA'}{QA'\cos\theta_2},$$

and, therefore, that in every layer

$$\tan\varphi=\tan\theta+\frac{u}{v}\sec\theta.$$

If u increases continuously and uniformly with elevation, and if the temperature and composition of the air are the same along the sound path, then it is possible to find an equation for the path, at least in the vertical plane through the origin. But as the conditions specified never strictly obtain, the solution is scarcely more than an abstract mathematical exercise, and therefore will not be given here.

FIG. 7.



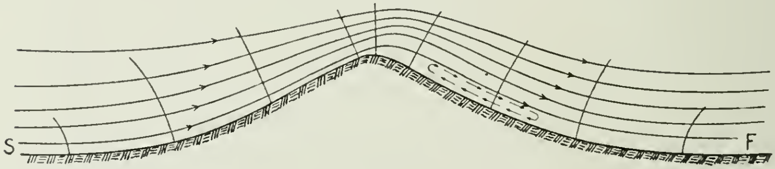
Distortion by wind of sound fronts.

From the above discussion of the effect of the bodily movement of air on the velocity and direction of travel of sound, it is obvious that its leeward and windward distributions may be radically different.

Let the centre of the distorted circle above S, Fig. 7, be the place of origin of a sound, and let the wind be blowing from right to left, as indicated, and increasing with elevation. Obviously, the velocity of the sound, and the consequent distances between the successive compressions and rarefactions will be greatest on the leeward side and least to the windward. The pitch, however, if source and observer are both stationary, will be the same. Furthermore, since the propagation is normal to the wave fronts, the sound is lifted to the windward as indicated in the figure, and thus becomes faint, if not quite inaudible, to one on or near the surface in that direction. On the other hand, it is driven down to leeward, in which direction it consequently is heard much farther and louder. All of which are matters of great importance in fog and other sound signaling. Indeed it is even possible for the lifted sound to windward to strike a shore cliff, or other object, and be reflected back in such manner that the echo alone is heard, and the friendly, warning signal thereby transformed into a fiendish lure to danger.

From the figure it is also evident that the sounds are much farther and better heard to the windward from elevated sources than from those near the surface—hence one of the great advantages in having bells in high steeples rather than near the ground. Likewise, sounds to windward, especially if originating near the surface, often are best heard at elevated points; better in the " crow's nest," for instance, than on the deck.

FIG. 8.



Sound crossing a mountain to leeward.

Another interesting phenomenon in this connection is the carrying of sounds from the windward to the leeward side of a mountain where they sometimes are so distinctly heard as to appear but a little way off. The wind, increasing in speed with distance from the surface, flows parallel, roughly, to the mountain sides—up one side and down the other. Hence the forward portion of a wave front tends more and more towards the vertical as it climbs the windward side of the mountain, crosses the ridge upright (if the wind is suitable) and then focuses onto the leeward valley beyond, all as diagrammatically illustrated in Fig. 8, in which *S* is the source of the sound and *F* its diffuse leeward focus, determined by the wind currents, as indicated in the figure by the progressive positions of the wave front.

The acoustical effects of oppositely directed winds in adjacent layers are worth considering, because such opposing winds frequently occur, for instance, when, in middle latitudes, the surface wind is from the east; in places of strong land and sea breezes; and in all trade wind regions.

The general effect in question is quite obvious from Fig. 7. That is, a sound made near the surface, by the firing of a large cannon, say, is first lifted on the windward side as indicated, and later, on getting into the oppositely directed upper current, tipped forward and downward, as readily conceived, though not indicated in the figure. In this way exceptionally loud sounds occasionally are heard a hundred miles or more from the source, and over extensive areas beyond a broad zone of silence.

Locating by Sound.

Sound Pointing.—It is well known that a very small difference in the phase of a sound as it enters the two ears generally is quite perceptible.[8] If then one could actually, or virtually by some artificial aid, stretch his ears far apart, and listen in at widely separated portions of the wave front he obviously could determine the direction of the sound arrival with great precision. And this has been done [9] by the aid of long, gently tapering, hollow cones, mounted some distance apart with their axes parallel, quickly adjustable in direction, and supplied, at their smaller ends, with aural tubes.

On correcting for refraction, due essentially to wind and differences in temperature (often impossible to do very accurately), the direction of the source, or, at least, its direction when the received sound was emitted, is determined.

Sound Ranging.—Not only is it possible to determine the direction of the source of a sound, but, by the aid of three listening stations, its exact location as well. In this way the positions of many enemy cannon were located during the world war.[10] The details of sound ranging, as the exact location of an object by sound is called, are numerous and their variations many. Nevertheless, the underlying principles are very simple.

Let *A, B, C,* Fig. 9, be three listening stations and *O* the place of origin, to be determined, of the sound pulse—place of the firing cannon, say. Let v be the velocity of sound in still air appropriate to the current temperature and humidity. Corrections can easily be made for any observed wind, but for simplicity it will be assumed that there is no wind, and hence no wind corrections. Let the sound pulse originating at *O*, be received at *A*, *B*, and *C* at the times t_1, t_2, and t_3, respectively.

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[8] Stewart, *Phys. Rev.*, 15, p. 432, 1920.

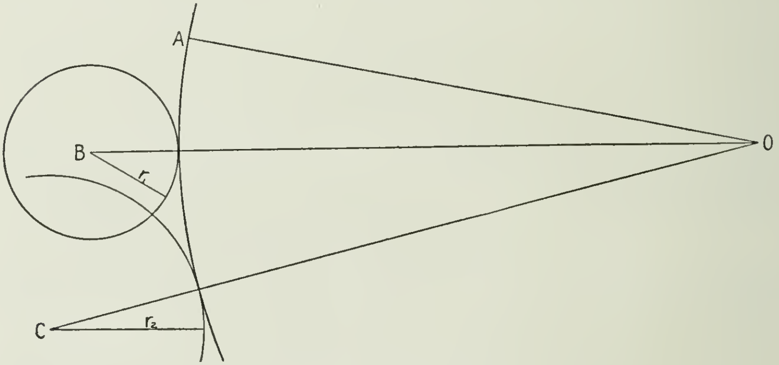
[9] Stewart, *Phys. Rev.*, 14, p. 166, 1919.

[10] Trowbrdge, JOUR. FRANKLIN INST., 189, p. 133, 1920.

Then, at the time t_1 the pulse is at *A*, and distant r_1, or $(t_2 - t_1)v$, from *B*, and r_2 or $(t_3 - t_1)v$ from *C*. Hence, *O* is the centre of that circle whose circumference passes through *A* and is tangent to a circle of radius r_1 about *B* and also to another circle of radius r_2 about *C*.

Another method of locating *O* is to note that it is on the loci of three several points, the difference of the distances of one of which from *A* and *B* is r_1, a constant; of another from *A* and *C* is r_2, a constant; and of the third from *B* and *C* is $r_2 - r_1$, likewise a constant. That is, it is at the intersection of any two, and hence all three, of the hyperbolas whose foci are *A*, *B*; *A*, *C*; and *B*, *C*, respectively, conditioned by $OB - OA = r_1$; $OC - OA = r_2$; and $OC - OB = r_2 - r_1$, respectively.

FIG. 9.



Sound ranging, or locating sound source.

Dissipation of Sound.—In an absolutely quiet and homogeneous medium the intensity of sound must vary inversely as the square of the distance from the source, except in so far as the mechanical energy of the waves is slowly dissipated into heat. In the ordinary atmosphere, however, at least near the surface, the intensity of sound decreases far more rapidly.[11] A portion of the excess in the rate of decrease of the intensity over that required by the inverse square law is due, no doubt, to internal reflections and refractions incident to temperature irregularities. However, the dissipation of sound generally is more pronounced the stronger the wind. Hence, since winds smooth out horizontal temperature irregularities and establish an approximately adiabatic cooling with altitude (1° C. per 103 metres) it follows that, at least when there is considerable wind, some other factor than reflection and refraction of the type just mentioned must be effective in dissipating sound. This factor appears to be the ordinary turbulence, or eddy motions, of the lower air.

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[11] Stewart, *Phys. Rev.*, 14, p. 376, 1919.

Since eddy motion is very irregular, both as to speed and direction, and since the velocity of only a moderate wind is several per cent. of that of sound (22 miles per hour equals about three per cent. of the velocity of sound) it follows that a sound front is greatly distorted on passing through such gusty winds as are common near the surface of the earth. These distortions obviously alter the direction of propagation—normal to the wave front—and on the whole increase the dispersion of the sound and rate of its enfeeblement.

To visualize the effect of eddies on sound a little differently, let an instantaneous distribution of atmospheric compressions and rarefactions, constituting a train of sound waves, be fixed in position except as acted on by mass movements of the air. Such inequalities would quickly be so intermingled by any moderately strong and turbulent wind as to practically obliterate the sound waves, and this same obliterative process is quite as operative, presumably, on travelling, as it would be on stationary waves. The time actually available for such operation is, of course, very brief, but it is sufficiently long, apparently, to permit a great reduction of the sound intensity.

Sounds to and from Elevated Points.—Balloonists, mountain climbers, and others, who have visited quiet places of considerable altitude, have reported two interesting sound observations:

(*a*) The balloonist, for instance, tells us that the higher-pitched sounds on the surface of the earth are heard to a greater altitude than lower ones of equal initial loudness. A chorus of spring frogs (*hylas*), for example, or the excited cackling of a flock of chickens, is heard after the human voice of at least equal loudness has faded away. This is in spite of the fact that the sounds of shorter wave-length are more rapidly dissipated by atmospheric irregularities than are those of longer wave-length, and due to the greater sensitivity, within certain limits, of the ear to the higher-pitched notes[12]–to our keener perception here, as also in the case of earthquake shocks, of acceleration than of amplitude.

(*b*) The balloonist may hear and understand persons on the ground while they cannot hear and understand him. This fact is so striking that it has repeatedly evoked wonderment and comments. Its explanation, however, is not, perhaps, immediately obvious. Probably several factors contribute to the final result, among them:

1. Since the density of the atmosphere is less at the level of the balloon than on the ground, it follows that the voice of the balloonist will be correspondingly weaker (carry less energy) than that of a person on the surface. At an altitude of half a mile, probably about the limit at which vocal communication is possible, the density of the atmosphere is still nine-tenths, roughly, that near the ground. Hence, the density factor, while in the right direction, is not sufficient to account for the commonly observed differences in audibility.

2. The pilot hears both the direct and the reflected portions of the voice below him (whether reflected by the horizontal surface or by objects on it) in substantially the same direction, while the ground observer hears the balloonist's direct voice from overhead, its chief reflection from below, and minor reflections more or less from all around horizontally. Just what the resultant will be in each case is not obvious, but it would seem that with respect to this factor also the balloonist has the better listening position.

3. The balloonist, even when up only half a kilometre, is in a region prevailingly of utter silence, where any occasional sound is most easily perceived. On the other hand, his surface interlocutor is immersed in a flood of sound, where the limit of audibility is soon reached. That this difference in noise environment is an important factor in the cause of the phenomenon under consideration is evident from the fact that the balloonist often can hear the earth echo of his own voice when he is unable to arrest the attention of persons below him.

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[12] Sabine, *Contributions, Phys. Lab. Harvard Univ.*, No. 8, 1919. Stewart, *Phys. Rev.*, 14, p. 376, 1914.

CHAPTER II.

SOUNDS OF METEOROLOGICAL ORIGIN.

Creaking of the Snow.

PROBABLY all, or nearly all, who have experienced a cold winter are familiar with the cheery cry of the snow as it is pressed against a hard surface by the steel tire of a wagon, for instance, or even onto a pavement by the heels of one's boots.

When the temperature is just a little below the freezing point, the snow, then in fine condition for snowballing, does not creak, and the track of the wheel is marked by a strip of more or less compact ice. On the other hand, when it is so cold that the snow will not ball, its voice is loud, and the track left by the wheel is now marked, not by a strip of compact ice, as before, but by a trail of crushed and powdered crystals.

In the first case, that is, when the temperature is only a little below freezing, the snow crystals obviously melt, to a greater or less extent, as a result of the pressure to which they are subjected, and undergo regelation immediately the pressure is removed. The yielding is gentle and progressive through melting and flowing, and not of that abrupt nature essential to the production of sound.

In the second case, however, or when the snow is too cold to melt under the pressure applied, its yieldings and readjustments are abrupt and jerky incident to the crushing of the crystals and their slippage in a dry condition over each other. It is these abrupt yieldings, these sudden breaks and slips of its dry crystals, that produce the familiar cold-weather creak and cry of the snow.

Thunder.

Cause.—Thunder, one of the most familiar and certainly the most impressive of all meteorological sounds, has been "explained" in many ridiculous ways, but generally, perhaps, just accepted. Any careful observation, however, will soon show that thunder is associated with lightning, and that the lightning flash always precedes the thunder. Clearly, then, thunder is somehow caused by lightning.

Now, it is known that sudden and intense heating, and molecular dissociation occur along the path of a lightning discharge. Hence a corresponding abrupt expansion, simulating a violent explosion, also occurs along this path; and this expansion in turn produces a compression wave in the surrounding atmosphere that travels outward exactly as would any other sound wave.

Musical Thunder.—It occasionally happens, when one is near the path of a lightning flash, that the thunder heard begins with a musical note. This is due to the fact that some lightning discharges—the flickering type—consist of a series of rapid flashes that occasionally are nearly enough regular, and of such frequency, as to produce a quasi-musical note.

Duration.—The long continuation of thunder is due, chiefly, to the great difference in the distances of the nearest and farthest points of the lightning path from the observer. If this difference is five miles, as it occasionally is, the duration of the thunder, owing to this cause alone, is roughly 24 seconds.

The duration of thunder is also prolonged by reflection. Occasionally the echo prolongation is very pronounced, but it is everywhere variable and uncertain.

Rumbling.—The great variations in the intensity of thunder that constitute its characteristic rumbling are due:

(*a*) To crookedness of path. The thunder starts from all parts of the discharge path simultaneously, or practically so, and thus the observer hears simultaneously the thunder from the whole of any portion of the path that happens to be at a constant distance from him. Now, as the path usually is very crooked, it generally happens that many portions of it are at one or another nearly constant distance from any given point. Hence, almost every peal of thunder is of irregular intensity, and as no two lightning paths are alike so also each peal of thunder differs from every other.

(*b*) To the sequence of discharges. Obviously, when a number of discharges follow each other in rapid succession—when the lightning is flickering—there is likely to be more or less interference between the several sound pulses resulting now in partial neutralization and again in reinforcement, the whole merging into an irregular rumble.

(*c*) To reflection. Reflection by mountains, hills and other objects may occasionally be effective in prolonging the noise of thunder and accentuating its rumble. However, mountains and hills are not nearly so essential to the rumble of thunder as occasionally they are said to be, for the rumble of the thunder, whether in the valley, on the plain or on the peak, is substantially the same.

Distance Heard.—Thunder seldom is heard more than 15 miles. This is much less than the distance to which cannon are sometimes heard. The circumstances in the two cases, however, are radically different. Thus, the sound energy from the cannon is relatively concentrated since it all starts from a single point and spreads out in a hemispherical shell, whereas, that of thunder starts, not from a single point, but from a crooked line often miles long. Furthermore, cannon often are fired when the surface air in which the firing occurs, is very still and otherwise in the best state for long transmissions of sound. Thunder, on the other hand, seldom occurs except when the winds are turbulent and the general conditions very adverse to sound propagation. Finally, the density of the air is greater at the cannon than along the lightning path, and hence its sound energy per unit volume, other things being equal, also correspondingly greater in the former than in the latter case.

Brontides.

From time immemorial low, rumbling, thunder-like noises (brontides, *mistpoeffers,* "Barisal guns," etc.,) of short duration, and that certainly are not thunder, for they often occur when the sky is clear, have been heard in many parts of the world, both singly and in irregular series. They appear to come from a distance, but of uncertain direction, and are most frequent in actively seismic regions.

Apparently, then, the true brontides (many other sounds have often been mistakenly reported as brontides) are only the rumblings of earthquakes too feeble for registration or other than aural detection. And this inference is strengthened, if not indeed confirmed, by the fact that earthquake adjustments have been known to occur in a long irregular series of shocks that became feebler and feebler until only the characteristic low rumbles (then properly called brontides) remained, as presumable evidence of their passage.

Howling of the Wind.

One of the compensations for being snowbound on a windy day is the pleasure of listening to the well-known howling of the wind as it sweeps by the chimneys and over the gables, and wondering where it gets its many voices, or, indeed, any voice at all. Nor is the wonderment yet over, for the problem of the howling of the wind has never been completely solved, at least not in the fullness of all the differential equations that tell the whole story. This much, however, is known: the howling, like the other æolian sounds discussed below, is due to eddy motions in the atmosphere immediately beyond the obstructing object. There is no resonance or other organ-pipe action, for the change from one pitch to another is not by jumps, as it is in all pipes, but gradual, through every intermediate value, in response to the varying wind velocity.

Let the direction of the wind make an appreciable angle with the roof and let the latter either project a little beyond the gable wall or, at least, come up flush with it. Under these conditions the wind will have its maximum velocity as it leaves the roof, and there in only a comparatively thin sheet. This sheet in turn, immediately it escapes the roof, drags along, through viscosity, some of the air just beneath it, and is itself slightly deflected in the direction of the consequent pull. In this way an abrupt change in the direction of flow is produced at the edge of the roof and hence an eddy will immediately start at that place. One effect of such an eddy, since it enters the current from relatively still air, is to slightly decrease the velocity of that current. It is quickly carried on, however, and the eddy-forming conditions thereby renewed. In this general manner, presumably, eddy after eddy is formed at the edge of the roof with such frequency and such approach to regularity as to produce a more or less musical note whose pitch increases with the wind velocity.

These sounds generally are much better heard indoors than out. This is largely, if not wholly, because one is there far less disturbed by the innumerable other outdoor noises, especially the continuous and annoying whisper of the wind right in one's ears—also an eddy effect.

Humming of Wires.

Few things, perhaps, have been more absurdly "explained" than has the well-known humming of telegraph and telephone wires, and that in spite of the fact that the correct explanation has long been at hand.

It was shown by Strouhal[13] that wind normal to a cylinder, such as a stretched wire, produces æolian tones even when the cylinder itself takes no part in the vibration; that the pitch of the note thus produced, independent alike of the material, length, and tension of the wire, varies directly as the speed, u, of the wind and inversely as the diameter, d, of the obstructing rod; and that the number, n, of such vibrations per second is given, approximately, by the equation

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[13] *Ann. d. Phys.*, 5, 216, 1878. See also Lord Rayleigh, *Phil. Mag.*, 29, p. 433, 1915.

$$n = .185\, u/d$$

the units being the centimetre and second.

Whenever the tone thus produced coincides with one of the proper tones (fundamental or a harmonic) of the wire, the wire itself, if suitably supported, then vigorously vibrates, normal to the direction of the wind, and thereby increases the loudness and also holds the pitch fixed over a considerable range of wind velocity. The sound in question, however, that is, the humming of telegraph and telephone wires, is not due to the elasticity of the wires (the pitch changes gradually with wind velocity and not from harmonic to harmonic), but to the instability of the vortex sheets their obstruction introduces into the air as it rushes by them. This obvious and, indeed, unavoidable deduction from Strouhal's experiments, just referred to, is abundantly confirmed by cinema photographs of water eddies, due to flow past a cylinder, made at the National Physical Laboratory. Vortex whirls developed at regular intervals, alternately to the right and left of the interfering cylinder, while the eddy mass vibrated from side to side in the same period, all as shown in Fig. 10, copied from Bairstow's "Applied Aerodynamics."

The complete mathematical analysis of these and similar vortices, giving the deduction of Strouhal's rules, and many others, would be both interesting and valuable, but it appears that this important problem has not yet been fully solved. Much progress, however, towards this solution, has been made by v. Kármán [14] and by v. Kármán and Rubach,[15] who have shown that evenly spaced vortices alternately on opposite sides is a stable arrangement, and the only one.

It is well known that the humming of telegraph and telephone wires is loudest when the wires are tightly stretched, as they generally are during cold weather. This appears to be because the eddies thus produced in the wind vary the tension on the wire, and rapidly the more so the tighter, or straighter, it becomes. Now these variations of tension are transmitted to the posts which in turn act as sounding boards, analogous to the sounding board of a piano, and hence largely increase the volume of the sound, whatever its pitch.

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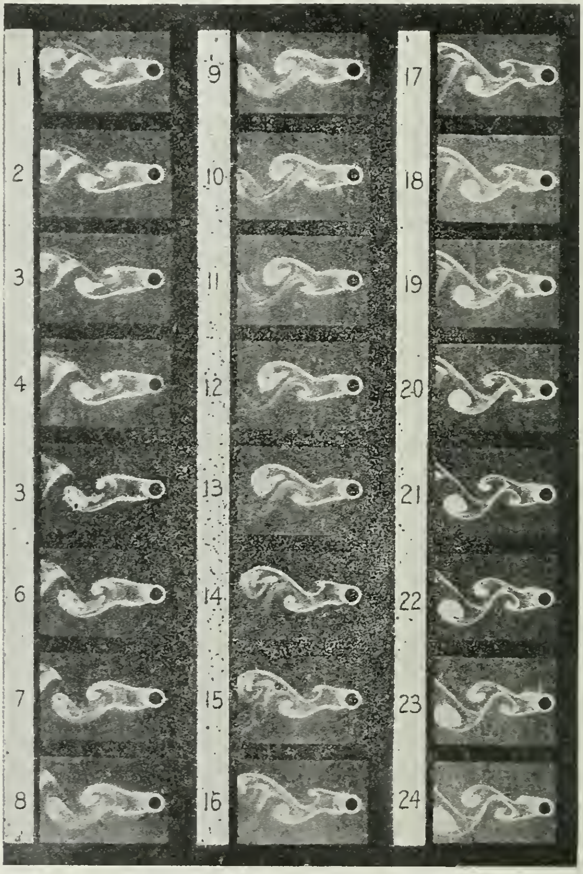
[14] *Göttingen Nachrichten*, 1912, *Heft*, 5, p. 547.

[15] *Phys. Zeit.*, 13, p. 49, 1912.

FIG. 10.



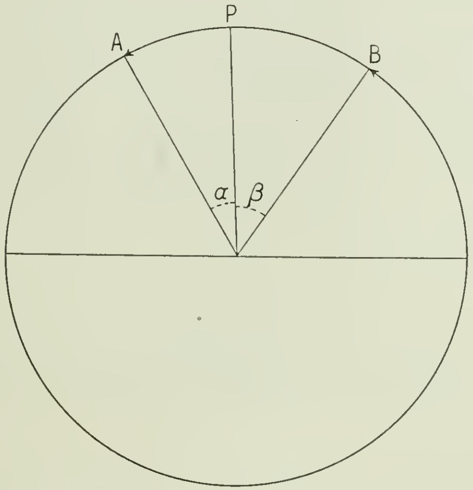
Eddies behind cylinder (N. P. L.).

Whispering of Trees.

From the experiments of Strouhal, above referred to, it is evident that pine needles, bare twigs, and even the branches of trees, must all produce æolian notes—that trees must have voices, even voices that are characteristic of the species. And they do. The muffled plaint of the oak at the wintry blast, for instance, has but little in common with the sibilant sigh of the pine. And the reason is obvious; the twigs and branches of the one, because relatively large and of many sizes, produce a multitude of low tones, while the innumerable fine needles of the other give a smaller range of high-pitched notes.

It may be granted that, as shown by experiment, each twig and other similar obstacle in the wind must produce an æolian note. But how, one must ask, do a multitude of such notes blend together—how are the pitch and loudness of the resultant related to the like properties of the constituents?

FIG. 11.



Phase circle.

To solve this problem, let two sounds have the same amplitude, but differ slightly in period. Let them start together with maximum displacement, or at the top, *P*, of the phase circle, Fig. 11. Let the phase position of the quicker, after a few intervals, and at the instant when the resultant amplitude is at a maximum, be at *A* (having described the angle $2n\pi + \alpha$, n being a whole number) and that of the slower at *B* (having described the angle $2n\pi - \beta$); let s be the velocity along the circumference of the phase circle of the slower, and $s + \delta s$ the corresponding velocity of the quicker. Then, since the combined amplitude is at a maximum

$$s \sin \beta = (s + \delta s) \sin \alpha, \text{ and } \beta > \alpha.$$

For the next maximum

$$s \sin (\beta + \delta \beta) = (s + \delta s) \sin (\alpha + \delta \alpha).$$

But

$$\delta \beta < \delta \alpha.$$

Furthermore, since the rate of increase of an angle is greater than that of its sine, the successive values of $\delta\beta$ will slowly increase so long as β and α are greater than 0, and less than $\pi/2$, and then decrease while they are greater than $\pi/2$ and less than π.

In short, the combination tone will have a varying pitch intermediate between those of its constituents. And this is also true of any number of constituent sounds—their resultant has a quasi-average pitch.

Analytically, assuming, for simplicity, equal amplitudes a and initially identical phase,

$$x = a \cos (2 \pi m t - \epsilon) + a \cos (2 \pi n t - \epsilon)$$

in which x is the resultant displacement at the time t after the initial count, when the phase epoch of each constituent vibration was ϵ, and m and n the respective frequencies.

Since

$$\cos (2 \pi nt - \epsilon) = \cos \left\{ 2 \pi mt - 2 \pi (m - n) t - \epsilon \right\},$$
$$x = a \cos (2 \pi mt - \epsilon) + a \cos \left\{ 2 \pi mt - 2 \pi (m - n) t - \epsilon \right\},$$
$$= r \cos (2 \pi mt - \theta),$$

where

$$r^2 = 2 a^2 \left[1 + \cos \left\{ 2 \pi (m - n) t \right\} \right]$$

and

$$\tan \theta = \frac{\sin \epsilon + \sin \left\{ 2 \pi (m + n) t + \epsilon \right\}}{\cos \epsilon + \cos \left\{ 2 \pi (m - n) t + \epsilon \right\}}$$

That is, the resultant is a quasi-harmonic in r and θ, each of which has the frequency $m - n$, while that of the combination is a varying intermediate between m and n.

A combination of two notes having different amplitudes and different initial phases gives equations substantially the same as the above, though, of course, slightly more complicated. Similarly, a multitude of sounds merge into a quasi-note whose pitch is the approximate average of those of the many constituents. Hence the whisper of a tree, whatever its volume, has substantially the same pitch as that of its individual twigs or needles; just as the hum of a swarm of bees is pitched to that of the average bee, and the concert of a million mosquitoes is only the megaphoned whine of the type.

The final law of sound essential to the explanation of the whispering of trees, namely, the intensity of a blend in terms of that of its constituents, has been found by Lord Rayleigh[16] in substantially the following manner:

Let the number of individual sounds be n, all of unit amplitude and same pitch, but arbitrary phase—conditions that approach the æolian blend of a tree. Clearly, if all the individual sounds had the same phase, and unit amplitude, at any given point, their combined intensity at that point would be n^2. If, however, half had one phase, and half the exactly opposite phase, the intensity would be zero. Consider then the average intensity when all the vibrations are confined to two exactly opposite phases, + and −. Now, the chance that all the n vibrations will have the same phase, + say, is $(\frac{1}{2})^n$ and the expectation of intensity corresponding to this condition $(\frac{1}{2})^n n^2$. Similarly, when one of the vibrations has the negative phase and the $n-1$ others the positive phase, the expectation is $(\frac{1}{2})^n n(n-2)^2$; and the whole or actual expectation

$$\left(\frac{1}{2}\right)^n \left\{ 1.n^2 + n(n-2)^2 + \frac{n(n-1)}{1\ .\ 2}(n-4)^2 + \ldots\ldots \right\} \quad (A)$$

The sum of the $n+1$ terms of this series is n, as may be indicated by a few numerical substitutions; or proved, as Lord Rayleigh (*l. c.*) has shown, by expanding the expression

$$(e^x + e^{-x})^n$$

into the two equivalent series

$$2^n\left(1 + \frac{1}{2}x^2 + \ldots\ldots\right)^n \qquad \text{(Maclaurin)}$$

and

$$e^{nx} + ne^{(n-2)x} + \ldots\ldots \qquad \text{(Binomial)}$$

developing the exponentials into series of algebraic terms, and, finally, assembling and equating the coefficients of x^2 in the two equivalent series, and solving for n. The value of n thus found is identical with the expression (A).

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[16] "Encyclopædia Britannica," 9th edition, Wave Theory; Scientific Papers, iii, p. 52.

That is, on the average, the intensity of the resultant of n sounds of unit amplitude, but confined, in random numbers, to two opposite phases, is always n, whatever its numerical value.

If, instead of the numbers of sounds in either of two opposite phases being random, the phases are random, the result, as Rayleigh has shown, is the same.

It should be noted that n is only the mean intensity of a possible range from 0 to n^2, and not the continuous intensity. But when the changes are rapid the fluctuations from the mean are correspondingly inconspicuous.

From the above two laws, namely, (1) that the pitch of a composite note is the approximate average of those of its constituents, and (2) that the mean intensity is the sum of the individual intensities, it appears (*a*) that the pitch of the æolian whisper of a tree is essentially that of its average twig, or needle, if the tree be a pine, and (*b*) that though the note of the twig may be inaudible, even at close range, the tree may often be heard some distance away.

Murmuring of the Forest.

Just as the æolian whispers of the myriads of needles on a single pine tree, or of the numerous twigs on an oak, for example, blend into a whisper of the same average pitch but vastly greater volume, so too the whisperings of a great many individual trees merge into the well-known murmur of the forest.

Roaring of the Mountain.

When a mountain well wooded along and near its top is crossed by a wind approximately at right angles to its axis, as indicated in Fig. 8, it often happens, particularly during winter when there are no protecting leaves on the trees (or at any time if the forest is pine), that, in the leeward valley, one hears a low sighing or moaning noise which, as the wind over the crest grows to a gale, gradually swells to a cataract roar. This, too, is only another instance, but a most striking one, at times even awe-inspiring, of the combined effects of myriads upon myriads of æeolian whispers, accentuated, indeed, along the valley through their crude focusing by the descending winds.

Odds and Ends.

In addition to the above, there also are numerous other sounds that might, more or less justly, be called meteorological, such as the *rustle of leaves,* due to the rubbing together of the foliage as trees and branches are shaken by the wind; the *roar and whir of the tornado,* due to the wrecking by the storm of all things in its path, to the wind eddies engendered by every obstruction, and to the more or less continuous rumble of thunder; the *patter of rain,* due to the successive falling of innumerable drops onto a roof, pavement, compact soil, and the like, or into a body of water; the *rattle of sleet* (frozen raindrops), due to the driving of the small ice pellets against any hard object—the windowpane, for instance; the *clatter of hail,* due to the fall of relatively large lumps of ice onto a roof, or other hard surface, and even (occasionally reported in connection with severe storms) to their striking together in mid-air; the *detonations of meteorites,* due to violent disruptions owing to their sudden and intense heating; the *sizzle of St. Elmo's fire,* the faint crackle of the constant stream of feeble electric discharges from mast tips or other points thus strangely illuminated; the *swish of the aurora,* due, apparently, to autosuggestion, and hence wholly subjective; and, of course, many more. But the explanations of all are easy if not immediately obvious, and hence even their further listing is quite unnecessary.

The Obligatory Use of the Metric System in Japan. CH. ED. GUILLAUME. (*Comptes Rendus,* March 29, 1921.)—The telegram from Shirio Kikkawa, Director of the Bureau of Weights and Measures at Tokio, announcing the adoption of the law rendering obligatory the use of the metric system in the Japanese Empire, must have been very welcome to the great metrologist at Sevres. In Japan, the metric system became legal in 1893. This was followed by a series of regulations aiming to accustom the people to the new units, and now these preparatory measures have logically culminated in compulsory adoption.

In 1913 the Parliament at Peking entered upon a similar program. China is now in the preparatory stages, and this is the case also in Siam. The action of Japan will, no doubt, greatly influence the other nations of the Orient.

G. F. S.

The Introduction into France of the Lacquer Industry from the Far East. MARIE-YVONNE LEMAIRE. (*Génie Civile*, February 26, 1921.)—The trees of which lacquer is the latex are diminishing in number in China and Japan while, on the other hand, the culture is attaining considerable proportions in Tonquin. Indeed, this country is the sole exporter of lacquer. During the war the technical employment of this substance was introduced into France by Verneuil, who had had much to do with the establishment of the industry and with the cultivation of the trees in Tonquin. After trying various European varnishes it was decided to lacquer the screws and other parts of airplanes. Here the unalterable character of the covering joined to its ability to bend without cracking proved of high value in keeping the blades well polished and contributed to the mechanical efficiency of propulsion. Those little brown men with flat noses so common in France in war time, the Annamites, did this work, using the methods they had learned in Asia. Nothing was to be desired so far as the success of the operation was concerned, but great skill and a long time were needed for the production of the finished product. The French Society for Indochinese Lacquers is seeking to reduce the cost of the process and has already solved some of the problems and is making progress with others. The time required for the hardening of the liquid has been reduced and in general it may be said that the industry is well on the way to be established in France on a modern basis, though the rate of exchange between the mother country and her foreign colony intrudes difficulties into the road to success.

G. F. S.

Potash from Nebraska Lakes. (*U. S. Geological Survey Press Bulletin No. 467*, February, 1921.)—Until 1915 the United States produced no potash salts from native material except wood ashes, but in that year potash was produced from kelp, dusts from cement kilns, and alunite, and from the alkali lakes of western Nebraska. The possibility of developing the reserves of raw material from the first three of these sources has been studied and reported on by the United States Bureau of Soils, of the Department of Agriculture, and the United States Geological Survey, of the Department of the Interior, but no Government report has heretofore been issued on the potash resources of Nebraska. In 1918 W. B. Hicks, of the Geological Survey, spent three months in the alkali lake region of Nebraska, visiting the plants and the productive lakes; collecting samples of brine, water, sand, and mud for analysis; and making a general study of the region. The information he obtained has been studied and careful estimates have been made of the quantity of potash salts in these lakes. These estimates and notes concerning the probable source of the potash salts are contained in Bulletin 715-I.

DETERMINATION OF THE DIRECTION OF ATMOSPHERIC DISTURBANCES OR STATIC IN RADIO TELEGRAPHY.*

BY

L. W. AUSTIN, Ph.D.

Head, U. S. Naval Radio-Telegraphic Laboratory, Washington, D. C.

The accidental discovery that the atmospheric disturbances, or static, come from more or less definite directions [1] was made independently by a number of observers in this country during the summer of 1918 in connection with the work then being done at various places to insure more perfect reception of European signals. It was then noted that along the coast of New England and the Middle States, the static appeared to come in general from the southwest. Very few quantitative observations, however, were made, but a general impression prevailed that the source of disturbance very probably lay in the hot plains of the Southwestern United States or Mexico.

WINTER AND SPRING, 1920.

In order to study static during the months when it is too weak in Washington to be of value for investigation, the writer was sent to Porto Rico in February, 1920.

San Juan.—On February 26th the apparatus was set up on the Naval radio reservation in San Juan near the old fortress San Geronimo, the instruments being sheltered in a tent. For the measurement of strength of signals and of the direction of the static it was not convenient to construct a swinging loop of sufficient size to permit satisfactory observations without amplification. Therefore, two standard 10 turn loops 50 ft. long and 8 ft. high with 6 inch spacing were placed at right angles to each other, with the apparatus so provided with switches that either one could be used alone or the two in parallel combination, either directly or in opposition.

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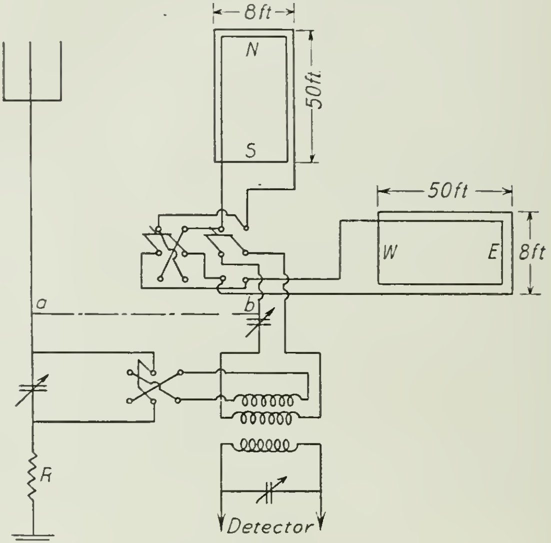
* Communicated by the Author.

[1] Note: Suggestions that static might be directional had been made earlier by Marconi, Pickard and others. See G. W. Pickard, *Proc. I. R. E.*, Vol. 8, p. 358, 1920.

The system was rendered unidirectional in the usual way by combining it with a small antenna. The circuits are shown in Fig. 1. This arrangement gave readings in eight directions, or every 45° around the compass, and values could be interpolated so that the directions were known with a fair accuracy to within about 15°.

Fig. 1.



Circuit for study of static characteristic curve.

Table I.

Typical Observations on Southerly Static; San Geronimo, March 15.		*Observations During Static Storm: Static Mainly W by N but with much Local; Cayey, April 16.*	
Direction.	Audibility.	Direction.	Audibility.
N	6	N	200
NE	20	NE	100
E	40	E	80
SE	60	SE	100
S	70	S	100
SW	40	SW	150
W	30	W	300
NW	30	NW	200

A typical set of readings is given under the date of March 15th in Table I. Here it is seen that the larger part of the static came from a point a little east of south. During February and

March the variation of the strength of the static with wave length was very noticeable, as is indicated under March 9th in Table II, the intensity increasing twenty times between 7000 and 18,000 metres. This is in marked contrast with the results at Cayey during the heavy static of April 14th, Table II, when it is seen that the intensity remains almost unchanged between the same limits.

Loiza.—On March 19th the receiving apparatus was moved about twenty miles east of San Juan and about four miles from the ocean. The antenna loop system was identical with that at San Geronimo. The observations were continued here until March 31st, being taken in part by Gunner Taylor. The results here were similar in character to those at San Geronimo, though signals were somewhat weaker.

Cayey.—The observations at Cayey, altitude 1300 ft., 30 miles from the north coast, extended from April 2nd to April 15th, the apparatus and arrangement of loops being the same as were used at the other stations. Observations showed that, taking into account the weakening of the signals with the advancing season, the reception at Cayey is decidedly superior to the stations along the north coast, while with the exception of the static storm, April 14th to 19th, the static conditions are more favorable. During this period the static, which had been mainly from the south in March, shifted so as to come principally from a little north of west (see Table I), and, since the periods of receiving difficulties seemed to be identical at Otter Cliffs and Cayey, it was concluded that the disturbances came from a common source. The afternoon static along the Atlantic Coast of the Northern United States had been found in general to come approximately from the southwest. The two lines of static direction from Otter Cliffs and Cayey would then cross each other in Mexico.

TABLE II.

Increase of Static with Wave-Length.

San Geronimo, March 9. *Cayey (Static Storm), April 14.*

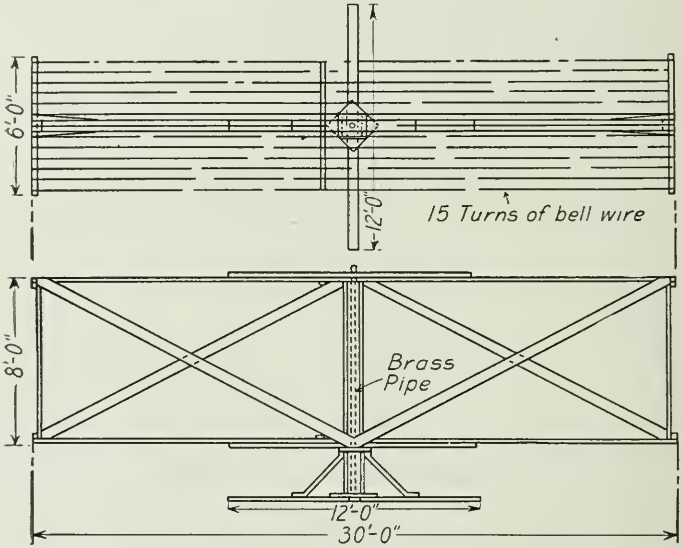
Wave-lengths, metres.	Audibility.	Wave-lengths, metres.	Audibility.
7,000	2	7,000	80
10,000	10	10,000	100
13,000	16		
18,000	40	18,000	100

SUMMER OF 1920.

In the summer work of 1920 the attempt was made to extend our knowledge of the direction of static to cover the Pacific Coast region and to render our information regarding the conditions on the East Coast and in Porto Rico more definite.

The apparatus used was as follows: The swinging loop of 15 turns, 30 ft. long, 8 ft. high and 4.5 inch spacing is shown in Fig. 2, while the circuits used are shown in Fig. 3. The parallel tuned circuit in the antenna simplifies the tuning of long waves on the small antenna and also seems to give a better balance than is obtainable with series tuning. The resistance R_1, 5000 to 30,000 ohms, serves to reduce the signal strength on the antenna to approximately that of the loop, while R_2, 200 to 1000 ohms, broadens the tune and enables the coupling to be changed without a too rapid shift of phase, thus rendering a complete balance easy. The balancing antenna used at different stations varied considerably in size. A single wire 100 ft. long and 30 to 50 ft. high was found to be satisfactory. The arrangement of coupling between the antenna and loop, as shown in Fig. 3, renders the loop unidirectional. With the switch S in one position, signals are received from one side while those from the opposite are cut off,

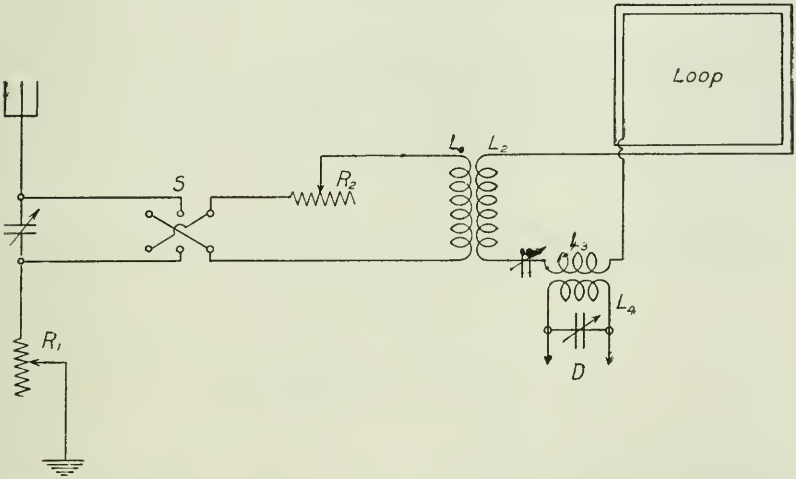
FIG. 2.



while with the switch reversed, signals are received only from the opposite side. Similar unidirectional combinations can be made between an antenna and a pair of underwater or underground wires, or, in fact, between any ordinary antenna and any type of directional collector.

For the determination of static direction the loop is turned and the coupling L_1L_2 adjusted so that when the switch S is thrown in one direction the static is a maximum, while with the switch in the opposite direction it is a minimum. The absolute direction in which the signals are strengthened and weakened with the switch in a certain direction is best determined by observations on a station in a known direction. When this is determined it is advisable to place a mark on one side of the loop corresponding to a mark on the switch, to indicate that the signals from this side of the loop are strengthened with the switch in the marked position. When the general direction of the static has been determined as described, the loop is turned to a position approximately at right angles to the indicated direction of the static. Then the switch S is rapidly reversed, the loop at the same time being moved slowly until the position is obtained where the sound of the static on the telephones is of the same intensity with the switch in its two positions. For exact readings the position of the loop expressed in degrees should be observed at which a difference in the

FIG. 3.



intensity of the static is just detectable on each side of the zone of equality. In the mean position between these two points, the loop is exactly at right angles to the static. This method of determining static direction is far more accurate than that of the simple unbalanced loop (radio compass). In fact, good readings can be obtained by the balanced method when no difference at all in intensity can be observed with the simple loop.

Table III.

Changes in Direction of Static with the Season.

San Geronimo, March 1–18.	*Loiza, March 19–31.*	*Cayey, April 14–25.*
80 per cent. South 20 per cent. W by N	50 per cent. South 50 per cent. W by N	30 per cent. South 70 per cent. W by N

During the past summer observations were taken daily at the Naval Radio Research Laboratory (Washington), and during certain periods at Astoria, Oregon; Bremerton, Wash.; San Francisco, Cal., and San Diego, Cal., with a few in Porto Rico and at other points.

Astoria.—The apparatus was set up on a dairy ranch about a mile from the radio station so as to avoid the influence of the station antenna and excessively strong interference. The loop was of the type already described and the antenna was a single wire running along the ridge pole of a barn 25 or 30 feet from the ground. The receiving instruments were covered by a tent and the work was carried on with the help of Radio Aid Marriott, of the Puget Sound Navy Yard, and his assistant. Observations were made between July 21st and July 31st, and the results of the measurement of static direction are given in Table IV. It was found in general that while the static was irregular in its direc-

Table IV.

Astoria Observations.

Direction.	Number of times observed.
NE	8
ENE	19
E	3
ESE	8
SE	8
S	1
Estimated accuracy 5°–15°.	

tion, the individual observations fell into groups, the largest group indicating disturbances from a point about 20° north of east. There seemed to be little connection between static and ordinary weather conditions.

Bremerton.—At Bremerton, as no suitable place was found in the Navy Yard, the loop was set up on a vacant lot near Mr. Marriott's house, with the instruments in a tent as at Astoria. The balancing antenna, about 90 feet long, ran to a pole in a neighboring lot.

Observations were begun on July 26th and Table V shows the summary of the directional observations up to August 23rd. From Table V it is seen that the observations are more irregular than at Astoria, on a few days even coming from the seaward side, no doubt on account of the Olympic range of mountains which lies between Bremerton and the ocean. In spite of the irregularity there seems to be a considerable concentration of static from the southeast.

TABLE V.

Bremerton Observations.

Direction.	Number of times observed.
WNW	1
NW	3
N	1
NE	4
ENE	5
E	13
ESE	13
SE	27
SSE	2

Estimated accuracy 5°–15°.

San Francisco.—The loop was here set up on the highest point of Goat Island, using as a balancing antenna a two-wire antenna about 50 feet high, originally intended for short wave spark work. Table VI shows the directional observations between August 11th and 31st. It is seen at once that the directivity of the static is entirely different from that observed at Astoria and Bremerton. Instead of being scattered over an arc of nearly 180°, all the observations except one, which may have been influenced by some local conditions, fall within an arc of 10°. This condition is remarkably favorable for a static barrage for reception from the west.

San Diego.—In San Diego the loop was placed in front of the distant control receiving station on North Island, with the receiving set in one of the receiving booths of the station. The observations, extending from August 26th to September 10th, are shown in Table VII, the wave length in most of the observations being about 11,000 metres. Here, as in San Francisco, the static was sharply directional from a point just south of east, none of the observations differing by more than a few degrees from this direction. The static intensity in general was not very different at the two places, with bad days perhaps a little more frequent at San Diego.

Table VI.

San Francisco Observations.

Wave-length . . . . . . 8,000–12,000 metres.

Date and time.	Direction of static.
Aug. 11: 3 P.M.	E
12: 10 A.M.	E
13: 2 P.M.	4° S of E
14: 3 P.M.	E
16: 10 A.M.	E
16: 3:30 P.M.	4° S of E
17: 5:00 P.M.	5° S of E
18: 4 P.M.	9° S of E
19: 3 P.M.	9° S of E
20: 2 P.M.	10° S of E
21: 3 P.M.	8° S of E
23: 4 P.M.	2° S of E
24: 1 P.M.	4° S of E
25: 3 P.M.	8° S of E
29: 6:30 P.M.	8° S of E
30: 2 P.M.	8° S of E
31: 4 P.M.	3° S of E

Estimated accuracy 2°–4°.

Washington.—During the summer, observations on the direction of static were made twice a day at the Naval Radio Research Laboratory. A summary of the afternoon results, July 1st to September 15th, is given in Table VIII. It was found that the direction of static is less sharply defined than at San Francisco and San Diego and that the reception barrages are generally much less perfect. The prevailing direction appears to be about 30° south of west, with a few observations scattered all the way between west and south.

Porto Rico.—Through some misunderstanding only a few observations on the direction of static have been forwarded from Porto Rico during the summer, but these indicate that the prevailing static has come from the south just as was observed last winter, instead of from a point slightly north of west, as found in the early spring experiments.

TABLE VII.

San Diego Observations.

Wave-length . . . . . 11,000–17,000 metres.

Date and time.	Direction of static.	Audibility.*
Aug. 26 : 3 P.M.	10° S of E	40
27 : 11 A.M.	E . .	40
27 : 3 P.M.	E	40
28 : 3 P.M.	5° N of E	10
30 : 3 P.M.	10° S of E	30
31 : 11 A.M.	10° S of E	20
Sept. 1 : 3 P.M.	10° S of E	15
2 : 3 : 30 P.M.	10° S of E	8
3 : 4 P.M.	10° S of E	8
5 : 3 P.M.	10° S of E	. .
8 : 11 A.M.	E	20
10 : 3 P.M.	E	40

Estimated accuracy 2°–5°, but absolute direction less accurately known than in San Francisco.

* Without amplification.

TABLE VIII.

Washington Observations.

Direction.	Number of times observed.
W	1
W by S	5
WSW	25
SW by W	22
SW	11
SW by S	6
S	4

Estimated accuracy 3°–10°

Our knowledge regarding the direction of static on the Gulf and Atlantic Coasts of our southern states is very meagre, but the little information available indicates that around New Orleans it comes mainly from a little west of south, while at Charleston it comes in part from the mountains a little north of west and in part from the southwest as at the more northern Atlantic Coast stations.

We may summarize our knowledge of directional static in the United States as follows:

1. The static on the Atlantic Coast of the United States comes in general from directions lying between south and west, largely from the direction of Mexico, but partly from the Allegheny Mountains.

2. The few observations on the Gulf Coast indicate a direction roughly southwest, *i.e.,* from Mexico.

3. On the Pacific Coast static is weaker than on the Atlantic and seems to come for the most part from nearby centres. In the north it is diffuse, but much of it seems to come from definite local centres among the mountains. Mr. Marriott has called attention to the fact that both at Bremerton and at Astoria a large part of the static comes from the direction of Mt. Ranier, an isolated peak and the highest in that part of the world. Further south, at San Francisco and San Diego, static is sharply directional and practically always comes from centres nearly east and probably among the nearby mountains.

4. In Porto Rico, according to our observations, static comes in general from one of two directions, either from a little east of south, probably from a centre in South America, or from a centre in the direction of southern Mexico a little north of west. This last centre may also be the one which produces the southwest static in the eastern United States. In Porto Rico there is also during the warmer months considerable diffuse static of local origin.

5. In general we may conclude that static comes from the land rather than from the sea, and when it appears to come from the sea there is generally land in the given direction at no great distance.

6. It may be, judging from the analogy of signals, that static which increases with wave length in a marked degree as that at Washington and the southerly static in Porto Rico, comes from a great distance; while the static that varies little with wave length, as at San Francisco and San Diego, comes from centres not far away.

7. In Washington it is generally observed that the late afternoon static in summer is much more sharply directional than that

of the forenoon, and that the directivity frequently becomes more pronounced as the static becomes more severe.

8. Two types of static in respect to tuning have been noted in our laboratory, one giving a pure shock effect is heard simultaneously over a wide range of wave lengths, and one in which the crashes are not heard simultaneously at different wave lengths. This last we have called the spectrum type, since it appears to consist of a large number of independent waves of different lengths forming a continuous static spectrum. There is some reason to believe that the spectrum type forms a large part of the directive static.

9. At present it is impossible to formulate any completely satisfactory theory of the origin of static, but it appears probable that it originates in the upper atmosphere in powerful discharges between air bodies at different potentials,[2] though it is difficult to understand how such discharges which give rise to electrical waves more powerful than those from the largest radio station, can take place without luminous phenomena. If the disturbing waves are formed in this way in the upper atmosphere, the wave front undoubtedly spreads out until it reaches the earth, where it grounds itself exactly like the radio waves from an aeroplane and then moves off with a practically vertical wave front as if it had come from an antenna on the earth's surface.

The results of the observations thus far made, fragmentary as they are, indicate plainly the importance of taking static directional observations wherever radio stations are situated, and warrant plans for a general static survey which shall extend eventually to all parts of the world.

On the Resistance of Copper Sulphate in Glycerine. A. GILMOUR. (*Phil. Mag.*, March, 1921.)—When a high resistance is needed that has small capacity it is found that a solution of copper sulphate in glycerine answers well. Such solutions are quite free from polarization. They are, however, hygroscopic and should be sealed to avoid contact with the air. Tables are given of the specific resistance of solutions of different concentrations.

An interesting *obiter dictum* is, "Glycerine has been known for a long time as a solvent of very wide range—at least as extensive as that of water."

G.F.S.

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[2] See Pickard's article cited.

Does an Accelerated Electron Necessarily Radiate Energy on the Classical Theory? S. R. MILNER. (*Phil. Mag.,* March, 1921.)—An electron whose velocity changes, either in direction or amount, is believed to send out energy in the form of electro-magnetic waves. An electron, forming part of an atom and moving about the central positive charge of the nucleus, is accelerated and ought to emit energy. This loss of energy should result in a progressive change in its velocity or in some change in its orbit. There is great difficulty in reconciling this conclusion with the observed fact of the permanence of the atom. "This question is of fundamental importance in modern theory, and would, I imagine, at the present time receive an affirmative answer from most physicists. Some apology seems necessary for attempting to open the question again at this date; and I should not have ventured to do so, but for the result of the consideration of a certain concrete case of accelerated electronic motion which is amenable to an accurate mathematical treatment. This example shows that it is possible to obtain, even on the classical theory, a solution for a particular case of the accelerated motion of charges, which satisfies completely both Maxwell's equations and the mechanical laws which characterize a conservative system, without any irreversible radiation of energy. A study of it enables us, I think, to prove that a certain step made in the deduction on the classical theory of the general necessity for radiation is not invariably a valid one, and to show that a comparatively minor modification of the boundary conditions of the solution is sufficient to do away with radiation in at any rate one case of accelerated motion."

G.F.S.

The Use of Cables for the Support of the Roofs of Workshops and Hangars. LEINEKUGEL-LE COCQ. (*Génie Civile,* March 5, 1921.)—Though the supporting of roofs in this way is far from new, it has assumed some importance recently in France, especially where a large space free from pillars is to be covered, as in hangars for airplanes and dirigibles. In the latter case this method of support makes it possible to roll to one side the whole side of the hangar nearly 500 feet in length, thus immensely facilitating the stowing away of the balloon even in a wind.

G. F. S.

Fixation of Nitrogen by Marine Algæ.—BENJAMIN MOORE, EDWARD WHITLEY, and T. ARTHUR WEBSTER (*Proc. Royal Soc. London,* 1921, B, xcii, 51–60) have demonstrated the fixation of elementary nitrogen by marine algæ in the presence of sunlight or full daylight. The elementary nitrogen is derived from the atmosphere and is dissolved in the sea water; it is converted into organic nitrogenous compounds by the algæ which obtain the necessary carbon from the bicarbonates of calcium and magnesium present in the sea water.

J. S. H.

THE STRUCTURE OF THE PHOTOGRAPHIC IMAGE.*

BY

C. E. KENNETH MEES, D.Sc.

Director of the Research Laboratory, Eastman Kodak Company, Rochester, N. Y.

THE UNEXPOSED EMULSION.

When a photographic emulsion is examined under a microscope, the sensitive silver halide which is distributed in the gelatine is seen to consist of crystals of several forms and of many different sizes (Fig. 1). These crystals are chiefly in the form of triangles or hexagons, some of the hexagons being irregular, while occasionally a thin rod-shaped crystal is to be seen. After careful study,[1] it has been determined that all these crystals belong to the regular or cubic system, but that instead of belonging to the group of crystals of which sodium chloride is typical, silver bromide crystallizes in the same crystal class as the alums. The flat crystals are produced by the development of the basal planes in preference to others, and in the case of the rod-like crystals truncation occurs in two dimensions, but these rods still belong to the same crystal class as the flat plates. As a general rule, the plate-like crystals of silver bromide are about 1/15th of their diameter in thickness, and they are found in the coating with their greatest surface parallel to the upper surface of the gelatine, this position being determined by the drying down of the coated emulsion.

When an emulsion is examined under polarized light, the crystals are seen to be strained and to produce double refraction, and in many cases these strains extend into the gelatine as if the dry gelatine were strained by the presence of the crystals. It has not yet been determined to what the strains in the crystals are due. It has been suggested that, on the whole, it is probable that the crystals contain gelatine and that the strain is due either to this or to the presence of silver iodide. All commercial emulsions contain some iodide, which does not crystallize out separately, but which enters into the structure of the silver bromide crystals and results in an increase of sensitiveness in the silver bromide in spite of the fact that silver iodide displays very little sensitiveness when used in an emulsion by itself. It is possible that the iodine atoms enter into the crystal structure, being substituted for bromide atoms. In this case, the crystal lattice will be deformed by the volume of the iodine atoms, so that the crystal is in a state of strain and therefore readier to react under the influence of light. In order to investigate this hypothesis, a study of the crystal lattice of silver bromide with and without iodide should be made by the methods of X-ray analysis, a beam of X-rays being passed through the crystals and the diffraction pattern studied. It may be possible by comparison of the patterns produced by crystals of pure silver bromide and by crystals in which some iodine has been substituted for the bromine to detect any deformation of the lattice produced by the substitution.

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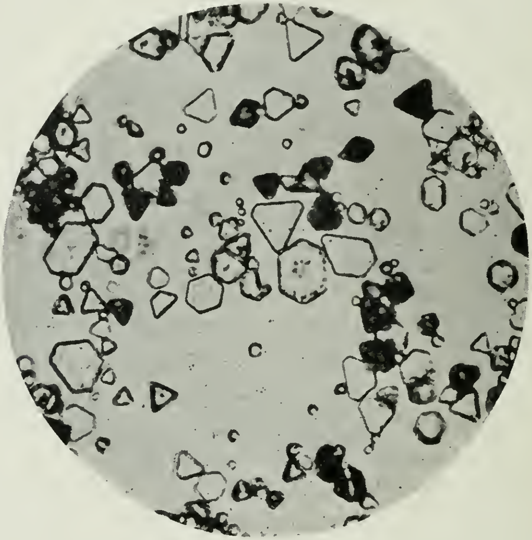
* Presented at a meeting of the Section of Photography and Microscopy held Thursday, December 2, 1920. Communication No. 109 from the Research Laboratory, Eastman Kodak Company.

[1] Monograph on "Silver Bromide Grain," Eastman Kodak Company, 1921.

Fig. 1.



Crystals in a silver bromide emulsion.

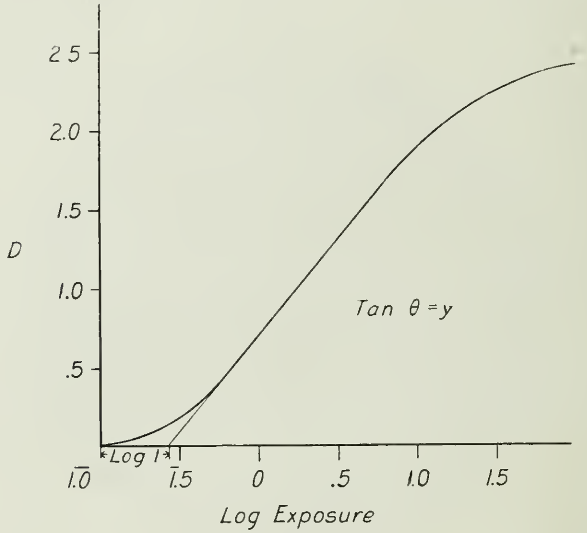
Since the emulsion grains are definitely crystalline, their character will be determined when the emulsion is precipitated, though it may be modified by subsequent treatment such as continued heat or digestion with ammonia. The conditions of precipitation of crystals from solution have recently been investigated both experimentally and theoretically, and the form of the precipitate has been found to depend principally upon the concentration and other conditions existing when the precipitation is made.

Photographic emulsions are formed by the addition of moderately concentrated silver nitrate solutions to bromide solutions of similar concentration in the presence of some gelatine and of an excess of soluble bromide. If we examine the precipitate produced at different stages during the addition of the silver nitrate solution, we shall find that as we continue to add silver, the number of crystalline grains increases, as would be expected, but that the increase is not proportional to the amount of silver added, so that some of the silver is precipitated not in the form of new grains but on grains already formed; that is, the crystals grow not only in number but also in size during precipitation, the first grains formed being very small and growing as the addition of silver is continued. The size of the silver bromide grains formed depends upon the amount of free bromide present, on the temperature, the concentration, and the rate of addition of the silver solution.

The photographic properties of an emulsion will depend upon the number of grains of different sizes present, and, in addition, upon the sensitiveness of the individual grains of each size. Now, photographic properties are expressed by the *characteristic* curve of the emulsion; that is, by the curve showing the growth of density after development corresponding to an increasing series of exposures. In order to obtain the curve, a series of exposures increasing geometrically is given. Thus, if the emulsion is held at a distance of 1 meter from a one candle power standard lamp, a convenient series of exposures would be ¼, ½, 1, 2, 4, 8, 16, 32, and 64 seconds. After development, the optical density of the deposit corresponding to each exposed area is measured, and a curve is drawn similar to that shown in Fig 2, which expresses the relation between the density and the exposure. For convenience, the exposure is plotted on a logarithmic scale so that the intervals between the steps are the same. Throughout a considerable portion of this curve, it will be seen that the density is proportional to the logarithmic exposure, and for this region the curve can be replaced by a straight line. Physically, this portion of the curve represents the range of light intensities in the original which is correctly reproduced by the absorption of light in the negative. At the beginning of the curve, in what is termed the *period of under-*

exposure, the increase of density is less than that which occurs through the straight line portion, the steepness of the curve rising from zero to the steepness of the straight line itself. In the period of over-exposure, density fails to rise proportionately with the increase of exposure and finally becomes constant, this constancy continuing for a long period, after which reversal sets in. In a paper published in the JOURNAL OF THE FRANKLIN INSTITUTE some years ago,[2] it was suggested that the shape of this curve should depend upon the distribution of the different sizes of grain in an emulsion, and, as an example of the dependence, a curve was given for a homogeneous emulsion which it was thought should give a simple curve with short over- and under-exposure portions (see Fig. 3), while it was thought that a curve having a longer straight line portion would correspond to greater variation in the size of grain of the emulsion, the grains of various sizes distributed around a mean replacing the greater uniformity of those of an emulsion, giving a curve with a short straight line portion.

FIG. 2.



Characteristic curve.

Dr. Ross[3] has recently investigated mathematically the relation between the shape of the curve and the distribution of the grain. He has assumed that the grains can be considered as divided into groups of grains of approximately the same size, the sensitivity factor of the groups varying in geometrical progression, so that the grains of each group have twice the sensitiveness of those of the group next to it. With every other factor kept constant, the shapes of the curves obtained by calculation are found to depend on the number of groups assumed to be present. In Fig. 4 are shown the curves obtained on the assumption that 1, 2, 3, and so on groups of grains are present, the number of groups being indicated by N. It will be seen that, as the number of groups increases, the length of the straight line portion of the curve as measured in exposure units also increases. When one group only is assumed to be present, the formula calculated by Dr. Ross would give the effective length of the projection of the straight line portion on the exposure axis as 15 exposure units. With 5 groups of grains, this would increase to 55; with 8, to 290; and with 10, to 1000. At the same time, the steepness of the curve corresponding to the maximum contrast obtainable diminishes, the maximum contrast for one group being approximately 0.82 D; for 5 groups, 0.58 D; 8 groups, 0.40 D: and 10 groups, 0.34 D, where D is the maximum

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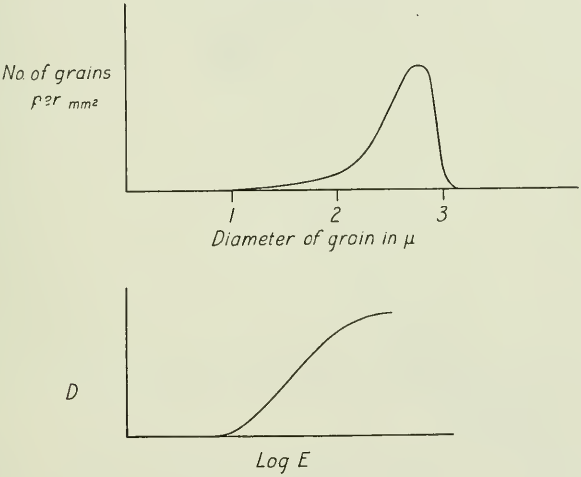
[2] C. E. K. Mees, JOUR. FRANK. INST., 1915, p. 141.

[3] F. E. Ross, *Jour. Am. Opt. Soc.*, 1920, p. 255.

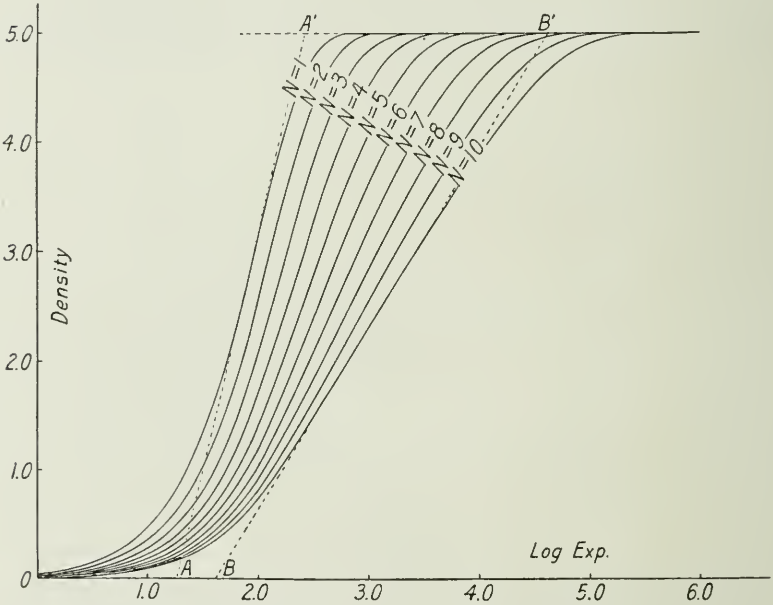
FIG. 3.



Suggested relation between frequency grain curve and characteristic curve.

density obtained from infinite exposure. Thus, a curve with one group of grains present would correspond to the properties of a process emulsion, having a short straight line portion and a very high maximum contrast, while a curve calculated for the 10 group, having an effective range of sensitiveness between the groups of 1 to 512, would correspond to a portrait emulsion with a long straight line portion and moderate contrast. This is in agreement with the views of Slade and Higson,[4] who ascribe the properties of a process emulsion to the uniformity of its grains.

Fig. 4.



Characteristic curve calculated for different numbers of grain groups.

Up to the present, very little experimental work has been published on the distribution of different sizes of silver halide grains, the only work that has given results depending upon the actual measurement of a large number of grains and the classification of the results. Thus, if an emulsion is spread out thinly upon a miscroscopic slide, so that only one layer of grains is obtained, this is then photomicrographed at a very high magnification—2000 to 3000 diameters, for instance—this copy is enlarged about 5 diameters, and a planimeter applied to measure the areas of the grains, it is then possible to construct a curve showing the relation between the area and the frequency with which grains of a given area occur.[5] While this process is laborious, it is quite possible to get excellent results with it. A curve showing the relation between the diameter of the grains and the frequency with which they occur is shown in Fig. 5; it will be seen that this curve is distinguished by the sharp point of maximum frequency at a diameter of .4μ. If, however, instead of plotting the number of the grains, we plot the total effective area of each size of grain, which is really the important characteristic of the grains, since the light absorbed depends upon the effective area and not upon the diameter of the single grains, we get the curve shown in Fig. 6, which may be taken as a first approximation to the true experimental distribution curve of an emulsion. This line of investigation must, of course, be pursued much further before the results obtained from it can be applied to the investigation of the relation between the grain distribution and the photographic properties of the emulsion, but it is to be hoped that this work will eventually prove successful in clearing up that relation.

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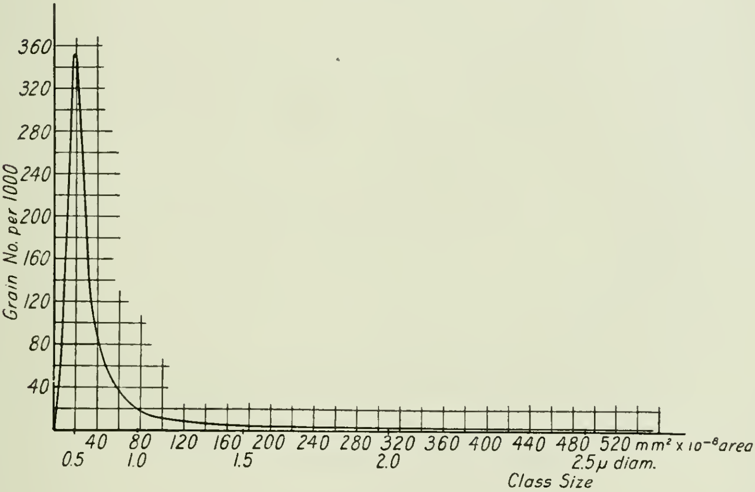
[4] *Phot. J.*, 1919, Vol. 59, p. 200.

FIG. 5.



Number of grains plotted against their area.

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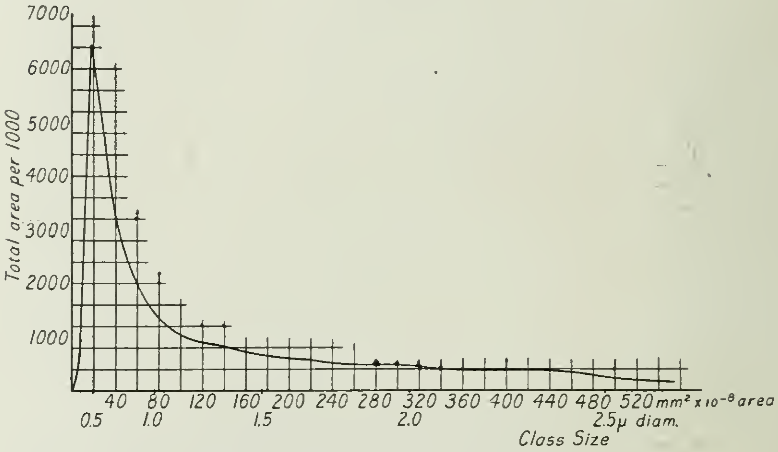
[5] S. E. Sheppard and E. P. Wightman, *J. Phys. Chem.*, 1921, Vol. 25, p. 181.

In addition to measurements made by photomicrography, it may be possible to measure the frequency with which grains of a given size occur in a photographic emulsion by automatic separation of the grains, this method depending upon physical effects due to the difference in size such as would occur in sedimentation or similar methods of separation.[5]

When the relation between the characteristic curve of an emulsion and the frequency with which the grains of different sizes occur was discussed in 1915, it was assumed that grains of any size require the same amount of energy to make them developable, and that consequently a given unit of energy would produce an amount of silver which would depend upon the mass of the grain by which it was absorbed. This would make large grains effectively more sensitive; that is, they would produce a greater density of silver than small grains owing to their size. This assumption was not based on any experimental evidence, but was the simplest assumption to make in the absence of any facts. There is now good reason to believe that it is not true generally and that grains of different emulsions, at any rate, even when of the same size, show specific differences in sensitiveness. In the case of grains of the same emulsion, an investigation of the distribution of sensitiveness according to size can be made experimentally.

Fig. 6.



Total area of grains plotted against their area.

Svedberg has recently published a study of the relative sensitiveness of grains of different sizes.[6] He diluted an emulsion with water so as to obtain a considerable separation of the grains and placed in the diluted emulsion a glass slide which was then drained and dried. In this way, a layer is obtained which is only one grain thick, and it may be assumed that the grains can be attacked by the developer without any question of penetration being involved. The prepared plates were exposed for different times, and after development the silver was removed by means of a silver solvent, leaving the undeveloped grains intact. In this way Svedberg was able to determine by difference the grains which had been made developable by exposure to light. He classified the grains in four groups: those which had areas from 0 to 6 square μ, from 6 to 12, 12 to 24, and 24 upwards. By making use of the known covering power of grains of silver, his measurements can be recalculated to obtain the curves giving the relation between density and exposure for the different groups of grains. These curves are shown in Fig. 7, and it will be seen that the different sizes of grains show very clearly a difference in sensitiveness, so that the different sizes of grains in an emulsion must be considered to show specific differences in sensitiveness. It is clear that by an extension of Svedberg's method, much information can be obtained as to the distribution of sensitiveness among the grains of an emulsion.

Slade and Higson[7] have measured the number of grains developable after exposure to light of various intensities, the time being held constant; or of constant intensity, the time being varied. They chose grains from a process emulsion which they state to be of uniform size, though probably the uniformity refers to only the larger grains, and there must have been a considerable number of smaller grains present unless some special method of separation was used.

The total energy incident upon a photographic plate has two components: the intensity and the time for which it is allowed to act. It was shown by Bunsen and Roscoe for the combination of hydrogen and chlorine to form hydrochloric acid, which takes place under the influence of light, that the amount of acid produced was dependent only on the product of the intensity and the time; that is, on the energy used. But it was first shown by Abney, and has often been confirmed by other workers, that this is not true for the photographic plate, and that, while with high intensities the law holds approximately, when the intensity is low, more energy is required than if the intensity is high. There is a difference, then, between a plate exposed to a light of one candle meter intensity for 10 seconds and another exposed to a light of

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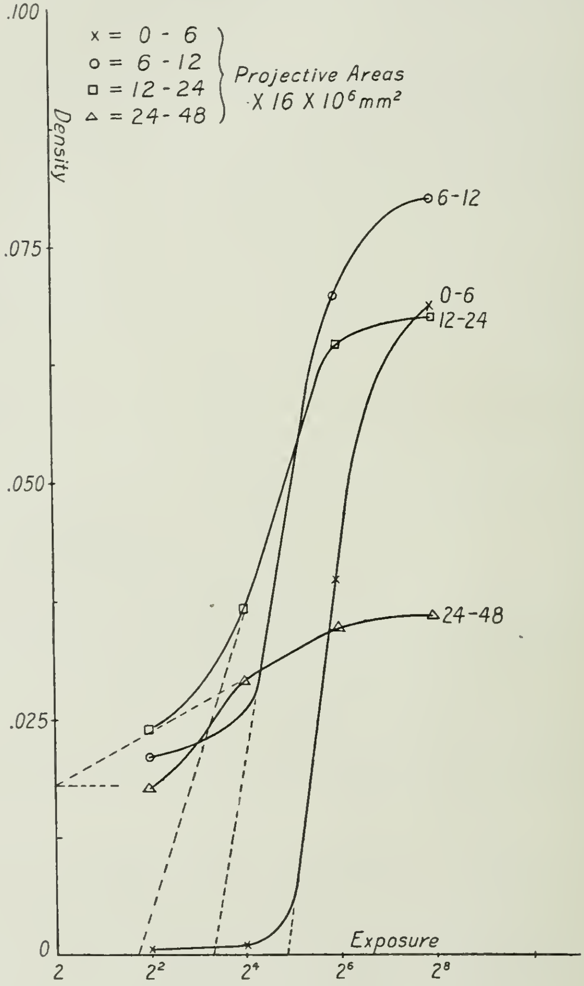
[6] T. Svedberg, *Zeit. f. Wiss. Phot.*, **20**, 36 (1920).

[7] *Proc. Roy. Soc.*, **A 98**, 154 (1920).

FIG. 7.



Characteristic curves of grains for different areas.

1/100th candle meter for 1000 seconds. Slade and Higson find that this failure of the Bunsen-Roscoe law occurs also in their experiments, and they conclude that for high intensities the effect produced is proportional to the intensity, time being constant, while for low intensities the effect is proportional to the square of the intensity. They find a difference in this respect between the action of monochromatic and polychromatic light, a difference which appears to require further investigation.

It was first pointed out by Abney also that if an exposure is given in small installments so that the exposure is intermittent, these installments do not add perfectly. One hundred consecutive exposures of 1/100th of a second with pauses between them are not equal to a continuous exposure of one second, and the amount of the defect depends upon the duration of the single exposures and upon the duration of the pause. The behavior of the silver bromide grain in these respects is as though the energy going into it underwent a transformation of some kind, and if the energy is supplied rapidly, there is a smaller total leak than if it is supplied slowly. It is as if one were filling a tank by the aid of a leaky vessel; the quicker the liquid was transferred to the tank, the less liquid would have to be carried in order to fill it; and if one did it intermittently, all the liquid would run out of the vessel, and it would have to be refilled each time that the work was resumed; so that, if it were necessary to fill a tank by aid of a leaky vessel carrying water from a faucet, it would obviously be to one's interest to work as quickly and as continuously as possible. What the mechanism is in the grain which produces this result, how the energy is stored, and why it shows this leaking effect are still unsolved problems. It must be remembered that the grain apparently preserves its energy indefinitely once it has been exposed. It remains to be proved whether a grain which has been exposed to an amount of light insufficient to make it developable still preserves the energy which has fallen on it and when exposure is resumed behaves differently from a grain which has not been exposed at all.

It may be useful at this point to recapitulate briefly the present state of our knowledge with regard to the unexposed silver bromide grains. They are crystals belonging to the regular system, showing strain, containing in most emulsions some iodide as well as bromide, and probably containing absorbed in them other substances such as soluble bromide, gelatine, etc. Their sizes are determined during the precipitation of the emulsion and are distributed over a range of diameters varying from ultra-microscopic grains below 1/10th μ in diameter to occasional grains as large as 10μ in diameter. The curve relating the sizes of grains to the number of each size present in an emulsion can be measured under the microscope and is probably related closely to the characteristic curve of the emulsion expressing the relation of density to exposure and therefore the photographic properties of the emulsion as a whole. Grains of the same size may vary in sensitiveness, and the sensitiveness of grains of different sizes in the same emulsion may vary from group to group. It can be shown that a geometrical relation between the sensitiveness of grains of different sizes is sufficient to account for the photographic properties displayed by emulsions prepared in different ways.

THE DEVELOPED IMAGE.

When they are developed, the silver bromide grains are transformed into metallic silver in a black spongy form, the silver occupying much the same position as the grains from which it was formed. The silver grains vary in structure according to the rate at which the silver is deposited, developers of low reduction potential giving grains which are more compact than those produced by the more usual developers. There is no experimental evidence, as far as I know, for the transfer of silver from one grain to another during development or for the growth of grains from silver in solution, at any rate under normal conditions. The silver bromide of each exposed grain is therefore transformed by development into an equivalent mass of silver.

The question has been raised as to whether the effective area of the developed silver grain is the same as or greater than the area of the silver halide grain from which it was formed. This point is under investigation at present. It is probable that the effective areas are substantially the same.

Since the deposit in a photographic plate is measured optically, a question of great importance is that of the relation of the absorption of light by the image to the mass of silver present. According to Beer's law, the amount of an absorbing material present in a solution, for instance, is proportional to the logarithm of the absorption, so that if we have a solution which transmits

1/10th of the light and another solution which transmits 1/100th of the light, the second solution will have twice the amount of absorbing material of the first solution. 'This is, of course, true only for monochromatic radiation or for substances which have no selective absorption—those which are black or gray. The silver image is of a sufficiently neutral color for this law to hold as far as selectivity is concerned, but the question arises as to whether we can assume that the law is valid for small particles such as are the grains of developed silver. This has been investigated both mathematically and experimentally.[8]

Experiment shows that to a high degree of approximation the amount of silver present in a photographic plate per unit area is proportional to the optical density, which is measured as the logarithm of the opacity, the opacity being the inverse of the transparency. Thus, the silver deposit which transmits 1/10th of the light is said to have an opacity of 10 and a density of unity. Such a deposit will correspond to 10 milligrams of silver per square decimeter of the photographic image. The mass of silver per square decimeter for unit density is called the *photometric constant,* and the question arises as to how far the photometric constant is dependent upon the size of the grains of developed silver and as to whether it is altogether independent of their distribution in the film. These problems have not yet been settled experimenally.

While it has been established beyond doubt that for a series of increasing exposures resulting in increasing densities, the photometric constant of a plate is a constant, it would seem probable that where the distribution of the same mass of silver throughout the thickness of the emulsion is quite different, the photometric constant may also be different. An extreme case would be given by images of the same optical density produced by ultra-violet light on the one hand and by X-rays on the other. In the first case, the grains of silver forming the image would be entirely upon the surface of the emulsion, while in the second they would be distributed uniformly throughout the depth of the emulsion. It would seem probable that in the second case, where the packing was not nearly so close, a greater mass of silver would be required for the same density than in the first case, where the grains are packed in the surface layer. If this is true for such an extreme case, it will also be true, though to a less degree, for images produced by light of different colors, since the penetration depends upon the wavelength of the light, and an image produced by red light, for instance, will be distributed to a greater depth in the emulsion than one produced by violet light.

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[8] S. E. Sheppard and C. E. K. Mees, "Inves. of the Phot. Process," p. 39. Hurter and Driffield, "Latent Image and Development," *Phot. J.*, 1898, p. 145. J. M. Eder, "Handbuch, III," (1903), p. 220. P. G. Nutting, *Phil. Mag.*, 1913, 26, p. 423.

THE GRAININESS OF THE IMAGE.

Since the final photographic image has a grain structure, it follows that under magnification any image must appear broken up to an extent depending upon the size and arrangement of the grains. In some cases, a developed deposit may appear grainy (that is, may show lack of homogeneity) to the unaided eye. The cause of this almost invariably is an agglomeration or grouping of the clumps made up of several of the ultimate silver particles which of themselves are so small as to be entirely beyond the resolving power of the unaided eye. When a deposit is viewed under magnifications insufficient to make just visible the ultimate grains, a lack of homogeneity is apparent which is due primarily to the presence of the first order clumps or aggregates composed of a few of these metallic silver particles. Under such conditions, the agglomerations of these clumps cease to have any appreciable effect on the grainy appearance of the deposit because the magnification is sufficient to separate widely the agglomeration centres. When the magnification is increased still further, so that the individual silver grains are easily visible, the graininess existing is due in a great measure to these grains themselves. It will be seen, therefore, that the lack of homogeneity in a photographic deposit depends upon various causes, according to the magnification under which the deposit is observed.

In speaking of grain, the scientific investigator usually refers to the ultimate silver halide particles of the emulsion, but when a case of lesser magnification is considered, such as exists, for instance, in the projection of motion pictures, or in the making of enlargements, the lack of homogeneity is due not to the ultimate grains themselves, but to aggregates of these grains composed of a relatively small number of the ultimate particles. To this type of non-homogeneity the word " graininess " is applied in order that it may be clearly distinguished from the effect produced by the resolution of the individual grains under much higher magnifications. The grainy appearance which can be observed by the unaided eye is due to further agglomeration of these aggregates and should properly be referred to as *graininess of the second order*. It is evident, therefore, that there are three phases in the non-homogeneity of a photographic deposit: (*a*) graininess due to the existence of the individual particles of silver, (*b*) graininess due to clumping of these particles, and (*c*) graininess due to the agglomeration of the clumps. It should be understood that these phases are not separated by any distinct line of demarcation, but merge by imperceptible gradations into each other. This impression is the result not only of the size of the grains of which the deposit is composed, but also of the distribution and arrangement in groupings of various kinds.

The graininess may be measured and specified numerically, the method used depending upon the assumption that the graininess of a deposit is directly proportional to the distance at which the appearance of graininess becomes just imperceptible, provided that all other factors upon which depend the ability of the eye to distinguish homogeneity are constant. For instance, consider an enlargement of a photographic density, the degree of enlargement being such that the lack of homogeneity (*i.e.*, graininess) is readily apparent when observed at, let us say, ordinary reading distance (*i.e.*, 12 inches). Now, if the viewing distance be increased gradually, a point will finally be reached at which this lack of homogeneity will disappear and the entire print appear to be of uniform brightness, free from all visible texture. The distance at which this condition appears may be taken as a numerical measure of the graininess of the enlargement. If another enlargement made to the same degree of magnification be viewed under precisely similar conditions, the distance at which graininess disappears when compared to the distance at which graininess disappeared in the previous case will provide a numerical specification of the relative graininess of the two deposits. The determinations made in this manner would, however, be subject to large errors; the readings would vary from day to day and be dependent upon the individual characteristics of the observer. In order to eliminate this, a method was devised in which the distance at which the graininess to be measured is compared with the distance at which a structure of known period disappears, crossline screens being chosen as the fixed structures with which the graininess is to be compared, so that a given graininess may be expressed by saying that it is equivalent to a screen of 3000 lines to an inch, it being implied by this that a 3000 line to the inch screen and the graininess in question would both just become visible at the same magnification.[9]

THE SHARPNESS OF IMAGES.

Since the image consists of grains, it is clear that the edge of an image, however sharp the edge of the theoretical image which produced it may have been, will be more or less ragged under high magnification. The sharpness of an edge in the case of a clearly defined image such as that of a spectral line will obviously be related to the size of the grain. Wadsworth considered that two lines should be separated in a photographic image if the distance between their centres was four times the diameter of a grain, but a very little experimenting will show that no such resolution as this can be attained, and that, especially with fine-grained materials, a much greater distance is required between two lines which are to be resolved clearly.

If we consider an optically sharp edge formed on a photographic material, such, for instance, as we might obtain by laying down on the material a razor blade, we shall realize that the light passing the edge will be reflected by the silver bromide grains of the emulsion, and that the light in the shadow of the edge will therefore be distributed somewhat as is shown in Fig. 8. We can calculate the falling off of the intensity according to the distance from the edge if we know the reflecting power of the grains of silver bromide, distribution, etc., or we can easily measure it by giving to such an edge a series of increasing exposures and then measuring the growth of the image inwards from the edge as the exposure is increased. Thus, suppose that a given exposure, a product of intensity and time, is required to form a visible deposit which we term the edge of the image. Then, for each intensity of the light reflected within the shadow of the edge there will be a corresponding time of exposure which will produce the image at the point corresponding to that intensity.

If, instead of a single edge, we use a narrow slit, we can measure its diameter for different times of exposure and draw a curve of the diameter against the exposure time. In this case, we shall find that the increase of diameter is proportional to the logarithm of the time of exposure, so that it follows the same law as the relation between the density and the exposure. The intensity of the light inside the shadow at the edge of an image on an emulsion falls off in the same way as the intensity of light passing into an absorbing medium. The constant of proportionality corresponding to the absorption coefficient may be called the *turbidity constant* (K), which can be obtained directly from the rate of the growth of the diameter of the image with exposure. The sharpness (S) may be defined as the rate of the fall of the density as the edge is crossed, or

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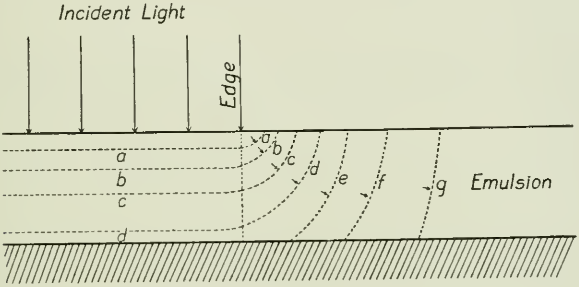
[9] L. A. Jones and N. Deisch, JOUR. FRANK. INST., 1920, p. 657.

FIG. 8.



Distribution of light at the edge of an image.

$$S = \frac{\text{Change of density}}{\text{Distance from edge}}$$

and this can be separated into the two factors due to exposure and development, so that

$$\text{Sharpness} = \frac{\text{Change of density}}{\text{Change in log intensity}} \cdot \frac{\text{Change in log intensity}}{\text{Distance from the edge}}$$

Now, the growth of density with the logarithm of intensity is the development factor or *contrast* of the image, which is measured from the characteristic curve expressing the relation between density and exposure, generally written as γ. In reality, the development action at the edge of an image is not the same as for an area of uniform density, and the numerical value of γ is appreciably different. The diffusion conditions at the edge of the image modify the development very greatly, introducing complications which are of great importance in astronomical photography. The change of logarithm of intensity with distance, measured by the growth of the image, is given by the coefficient which we have termed K. Therefore:

$$\text{Sharpness} = \frac{\gamma}{K}$$

It will be seen that this formula[10] ignores the grain size itself, the reason that fine grained emulsions give images sharper in outline than those of coarser grain being that fine grained emulsions usually have a high contrast (γ) and a low turbidity, so that they give good sharpness of an edge apart from all questions of grain. If materials are used, however, which have high turbidity and low contrast, they will not give sharp edged images even though the grain size may be small.

The actual sharpness of edges was measured by placing a razor blade or sharpened edges of a slit upon the material and allowing light to fall vertically upon it. After development, the falling off of density at the edge was measured by means of a microphotometer, and the actual density plotted against the distance from the edge. This curve is shown in Fig. 9. The slope of this curve may be taken as being a numerical measure of the sharpness. If the light falling upon the edge varies in wave-length, then it is found that the sharpness itself will vary with the wave-length. This would be expected, since both the gamma and the turbidity depend upon the wave-length. From the measured variation of γ and turbidity with wave-length, the sharpness wave-length curve can be computed, and the computed curve agrees sufficiently well with that observed to show that the general reasoning involved in sharpness is correct.

The form in which sharpness is of importance generally in photography, however, is that of resolving power. If we make a very small photograph of a picture and then examine it under a microscope, we shall, of course, find the detail broken up by the grain structure. We may, however, use a much finer grained plate without obtaining better detail, although the structure of the grain is now not so apparent. Finally, by using a plate of high resolving power, all the details of the picture appear sharp in spite of the great magnification which it has received. The resolving power of a plate is dependent upon two factors: upon sharpness, which in turn is dependent upon the photographic contrast and the turbidity, and upon the graininess of the plate, which introduces a subjective factor of discrimination. Resolving power is found to vary with the wave-length in the same way as sharpness, thus indicating very clearly its dependence upon the latter, but in practice

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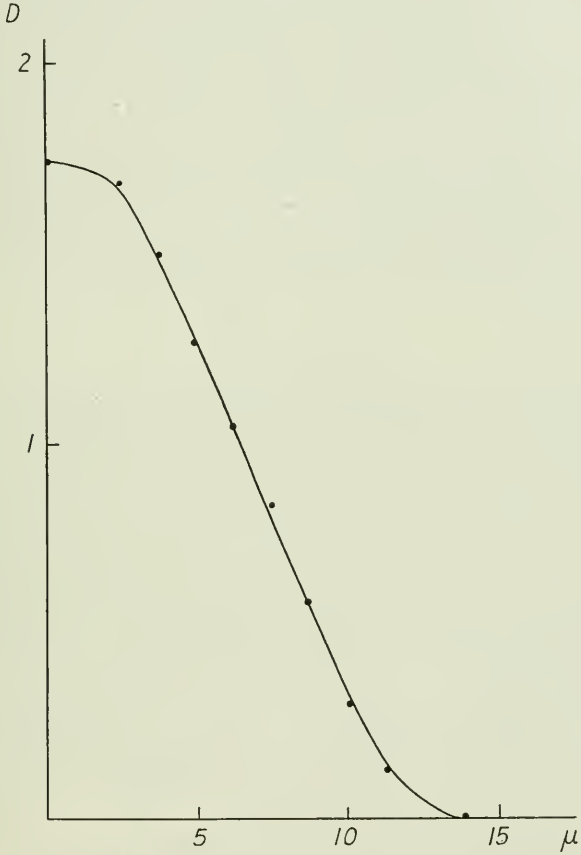
[10] Cp. F. E. Ross, *Astrophys. J.*, 1920, 52, p. 201.

FIG. 9.



Measured sharpness at the edge of an image.

it is convenient to use a method of measuring resolving power which does not depend upon the difficult measurement of the sharpness of the edge of an image, and for this purpose an image is formed of a converging grating in which the lines are always spaced at a distance apart equal to their width. This converging grating is photographed by means of a small camera at a considerable distance, so that the image of the grating on the plate is only about one millimeter long, and since the spacing of the grating is known, a numerical expression for resolving power can be found by observing how far down the grating the image is resolved. This resolution is usually expressed in terms of the distance between two lines which will just be separated in the photograph. The measurements so made bear out the conclusion that the resolving power of an emulsion is the product of the three factors—graininess, turbidity, and contrast—all three factors playing a part in the determination of the resolving power as observed and thus giving a very complex relation between the size of grain, the wave-length, and the effective resolving power, while the practical resolving power obtained, like the sharpness of an edge, is affected by the diffusion phenomena of development which at the present time are very imperfectly understood.

Rochester, N. Y.,
February, 1921.

The Construction of the Highway System in Morocco. (*Génie Civile,* February 26, 1921.)—From 1913 to 1919 the French Protectorate in Morocco built more than 2000 km. of highways. The indigenous population furnished an abundance of workmen at low wages whose employment had also a serious political aspect, since it helped to render contented the inhabitants of this land which had only recently come under French influence and which like all other parts of the earth suffered from the economic conditions resultant from the war.

Owing to fuel difficulties in war time mechanical road-rollers were often replaced by lighter and slower rollers drawn by animals. This arrangement had the merit of saving money, especially in the south of the country, where 5 or 6 francs a day would hire a camel and his driver. A roller, weighing 5 tons, drawn by eight camels, cost 40 centimes per ton-kilometer for operation, while a roller propelled by a gasoline motor cost from 50 to 75 per cent. more.

G. F. S.

The Constitution of the Alkali Metals. F. W. Aston. (*Nature,* March 17, 1921.)—The method of positive ray analysis is applied to the alkali metals. Lithium has already been found to consist of two isotopes of atomic weights 6 and 7. Sodium atoms are of one kind only; potassium is made up of two isotopes having the atomic weights 41 and 39, the latter greatly preponderating. There are two rubidium isotopes, 85 and 87. Thus far only one type of cæsium atom has manifested itself, but the evidence in this case is not final.

G.F.S.

ANISOTROPIC LIQUIDS.*

BY

J. STEPH. VAN DER LINGEN, B.A.; F.P.S. (London);

Government Research Fellow, Lecturer University of Cape Town, James Buchanan Johnston Scholar, Johns Hopkins University, Member of the Institute.

The following researches were commenced at the University of Zurich in 1913, and were devoted to the elucidation of a point of much importance with regard to the real inner constitution of anisotropic liquids. To make the point of issue plain, it will be well to give a short account of some of the work that has been done on such liquids, and of the theories of their structure that have been advanced in recent years.

INTRODUCTION.

Solid Crystals and Their Optical Properties.—" The study of crystalline structure, both in its experimental and theoretical aspects, during the past century, has led to the conclusion that the whole of the physical, geometrical and mechanical properties of crystalline solids are in harmony with the following definition. A single individual crystal is a homogeneous structure, that is, a structure the parts of which are uniformly repeated throughout, so that, ignoring the boundaries, corresponding points have everywhere a similar environment. The correspondence between this statement and the facts is so complete as to prove definitely that the characteristic which distinguishes crystalline solids from other bodies, is this homogeneity of structure of the individuals of which they are composed.

" From the principle of structural homogeneity may be at once deduced all the various forms, in which the empirically observed fundamental laws of crystallography have been stated, such as the law of zones, the law of rational indices, etc., and it is to be concluded that the distinguishing feature of external regularity of form, assumed by an individual crystal, is correlated with the class of homogeneous structure to which it belongs."

Since the time of Bravais (1850) it has been accepted as axiomatic that the position of equilibrium of the molecules of a crystalline body form some definite geometrical figure, whereas the molecules of all other bodies are irregularly distributed through space. The configuration of the centres of force determine the space-lattice of the crystal, and the type of the lattice is revealed by the external regularity of form of the rectilinear figures.

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* Communicated by Dr. Joseph S. Ames, Associate Editor.

On account of the symmetrical arrangements of the centres of force in a space-lattice, a crystalline solid possesses definite elasticities along definite directions, and these elasticities are assumed to be responsible for the optical properties of crystals.

On account of their high order of symmetry, cubic crystals do not show double refraction, whereas pyramidal and rhombohedral crystals have only one direction along which double refraction does not take place, that is, they possess one optic axis, and are called uniaxial as distinguished from crystals possessing prismatic, oblique or anorthic symmetry, which are biaxial.

When *convergent* polarized light is transmitted along the optic axis of a uniaxial crystal, and the emergent beam is examined by a Nicol's prism, it is found that the crystal displays rings and crosses which are symmetrical about this axis. Similar symmetrical figures are displayed by biaxial crystals in convergent polarized light, but in this case, the figures are symmetrical about the two optic axes.

Furthermore, on account of the difference in the elasticities along different directions in a crystal, the coefficient of absorption of light sometimes varies to such an extent that the crystal assumes different colors in different orientations with regard to the direction of transmission of light, that is, it displays dichroism.

These optical properties are sometimes taken as an index to the class of symmetry to which a given crystal section belongs, *e.g.* rock sections. We shall discuss the converse argument when we review Vorländer's theory of anisotropic liquids.

ANISOTROPIC LIQUIDS.

In 1888 Reinitzer discovered that Cholesteryl benzoate melts at 140° C., and changes to a turbid fluid, which is double refracting up to 179° C., where it becomes isotropic,[1] and in 1890 Gattermann recorded similar phenomena in the case of p. azoxyanisole and p. azoxyphentole. Since Reinitzer's discovery, which was followed by numerous similar discoveries, and preparations of new compounds endowed with doubly refracting properties in the liquid state, several theories have been advanced to account for this phenomenon.

THEORIES OF ANISOTROPIC LIQUIDS.

G. Tamman classified these anisotropic liquids under the heading of emulsions, and he attempted to explain the fact that the observed phenomena may be retained for days by assuming that the suspensions are endowed with a long life.[2]

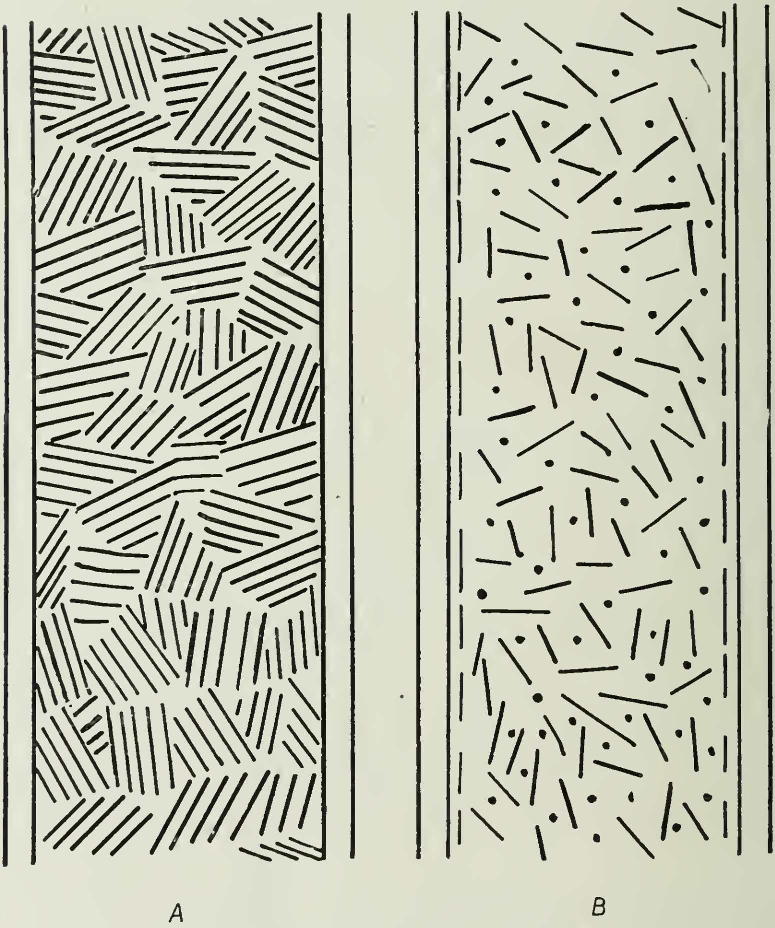
This theory gives no solution to the optical properties, such as double refraction, dichroism, etc.; and it was on this account that Emil Bose,[3] after having reviewed the evidence in favor of and against the emulsion theory,[4] on the evidence of Vorländer's chemical researches,[5] assumed that the molecules of those substances which may pass into anisotropic liquids have the form of ellipsoids of revolution, and that "swarms" of such molecules move in aggregates in the liquid, and thus cause the optical phenomena.[6]

The assumptions which Bose made are based on the results of Vorländer's researches. The latter showed that only such compounds as consist of long linear molecules give rise to the phenomenon of anisotropic liquids.[5]

On heating the crystal which gives rise to the anisotropic liquid, it gradually becomes plastic, and at a definite temperature begins to melt. Bose's theory is that, since the molecules are ellipsoidal, they are initially constrained to move parallel to one another and thus form "swarms" of similarly orientated molecules. This state of affairs will exist as long as the mean free path between the molecules is less than half the major axis of these molecules, but as the temperature increases, the mean free path increases and consequently the molecular swarms gradually decrease in size and finally break up altogether. At this stage the liquid is amorphous and perfectly transparent. The turbidity of the anisotropic phase was explained as due to diffusion from the edges of the "swarms"; which are not necessarily similarly orientated although their molecules are similarly orientated (See *A* and *B*, Fig. 1). Subsequently Bose found that not only is the transition from Crystal ⟶ anisotropic liquid perfectly sharp and accompanied by a definite absorption of heat, but also: that the transition from anisotropic liquid ⟶ Isotropic liquid is gradual and is accompanied by a small absorption of heat;[7] moreover he also showed that under certain conditions thick layers of anisotropic liquids are perfectly transparent.[8] This latter discovery is in accordance with the theory of swarms, whereas the emulsion theory is feelingly silent on this point, as well as on most of the optical phenomena.[9]

In order to test his theory, Bose argued as follows: When the substance is in the anisotropic state, it consists of swarms of similarly orientated molecules, which will require a definite time to flow through a capillary tube when the diameter of the tube is large in comparison with the size of the individual swarms, and the time of efflux in this phase must be less than the time of efflux

FIG. 1.



when the liquid is isotropic, because in the latter case the molecules move in any direction, hence the efflux in the anisotropic phase must vary with the temperature, because the "swarms" first decrease in size and finally break up; that is, the rate of efflux increases as the size of the swarms decreases, but decreases when the haphazard motion sets in.

The optimum state of flow is when the velocity at the centre of the tube is a maximum and zero at the circumference, that is, when the product of the pressure P, and the time of efflux T, for unit volume is constant. Poiseuille's state of flow $P_pT = K$.

Now by increasing the pressure beyond a definite limit this relation should not hold because the flow becomes entirely different. In this state characterized by $P_h = K_h/T^n$, the swarms will be whirled against the sides of the tube, as well as haphazardly against one another, and will consequently break up. This state of affairs will favor the tendency of isotropy; consequently the rate of efflux near the transition point, under a high pressure, should become more and more nearly equal to the rate of efflux immediately beyond the transition point. In the isotropic region, however, the viscosity will be independent of the pressure, because there are no molecular swarms.[10]

In his experimental researches Bose found that the difference between the rates of efflux in the two regions did actually become less as the pressure increased and these results were thus considered a confirmation of his theory.

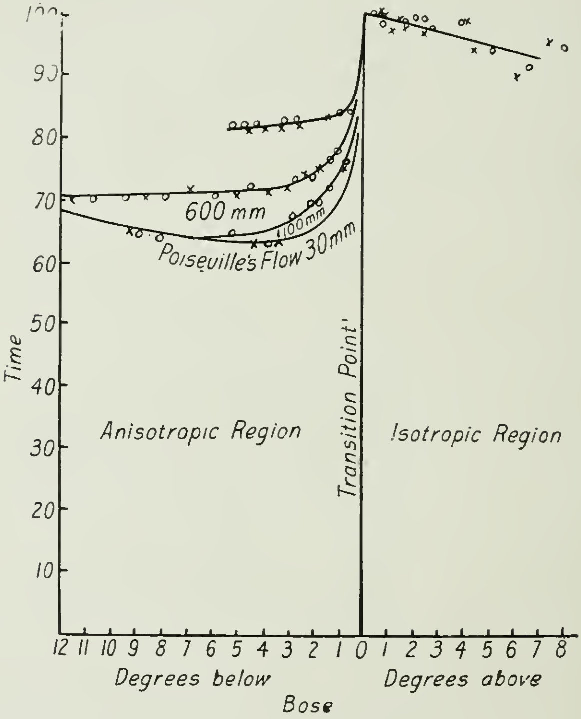
Fig. 2 gives a graphical representation of his results. The time of efflux is put = 100 at the transition point, where the viscosity is a maximum. The slight variations in the time of efflux in the isotropic region were considered to be due to errors of observation, hence an average curve was drawn.

This viscosity anomaly was further explained by considering the dimensions of the molecules, which flow axially out of the tube in the Poiseuille state and haphazardly under all conditions in the isotropic state. If they be ellipsoids of revolution whose axes are "*a.a.c*" where "*a*" is small in comparison with "*c*," the maximum viscosity is to the minimum viscosity as 3 : 2, that is, the viscosity in the anisotropic phase below the transition point is 2/3 of the viscosity just above the transition point. If the axes of the molecule are "*a,b,c*"—probably anisotropic liquids which have two anisotropic phases, this ratio may even become 1/3.[11]

PRESSURE AND VELOCITY EFFLUX THROUGH CAPILLARY TUBES.

At the instigation of Bose, F. A. Willers carried out a detailed set of observations on the variation of efflux with pressure in the case of pure emulsions, both below and above the critical temperature.[12] He showed conclusively that the same pressure-efflux variation observed in the case of anisotropic liquids is shown by emulsions, but there is this difference, that this variation is also displayed beyond the critical temperature, that is, the constant pressure curves, plotted against the temperature below and above the critical temperature, have a similar type of slope. He arrived at the conclusion: "This work shows that the viscosity variation with pressure does not furnish any proof in favor of the different theories."

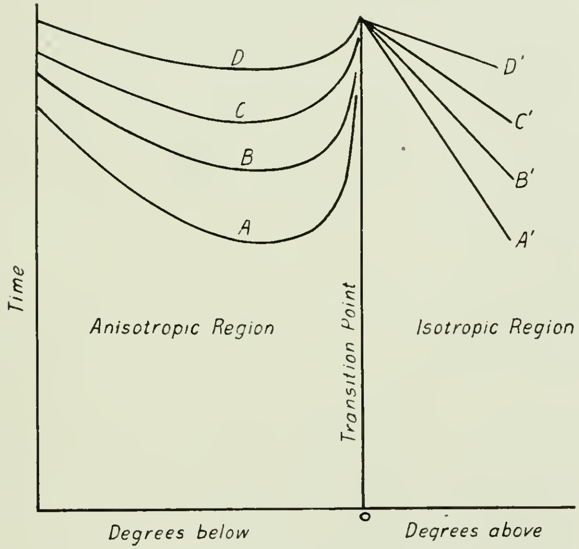
FIG. 2.



Emulsions—"Swarms".—Subsequently M. W. Neufeld showed that the viscosity of anisotropic liquids in the isotropic phase also varies with the pressure; and he pointed out that, if

Bose had continued his constant pressure curves for a range of temperatures in the isotropic phase, he would have found that the "near lying" points of limited observations were in reality each belonging to a smooth curve.[13] Hence these phenomena for anisotropic liquids and emulsions are identical (Fig. 3 according to Kruger). In 1908 Bose [14] pointed out the importance of investigating the influence of pressure on the efflux of liquids, and in 1909, subsequent to publication of Willer's results for emulsions, he gave a record of observations of the efflux of pure liquids through capillary tubes.[15] This work which was published to draw attention to this important problem, was carried on by W. Sorkau, who arrived at the conclusion that there are three states of turbidity which are dependent on the pressure to which the liquid is subjected.[16] The second type, however, has been shown to be a transition "backwards and forwards" between the first type and the third type.[17]

FIG. 3.



In the Poiseuille state of flow the viscosity decreases with the temperature and the temperature coefficient depends upon the chemical constitution of the liquid.[18] In type one turbidity, the viscosity also decreases with the increase of temperature, and not only is this decrease uniform but also its coefficient is practically the same for different substances. The third type, which we shall now designate "second" type, is wholly different from the first. Here the change of viscosity with temperature is practically zero.

Thus the states of flow are *Poiseuille, Turbidity One, Turbidity Two*, respectively as the pressure range is increased, representing the cases where: (1) There is a variable temperature coefficient of viscosity, depending on the chemical constitution; (2) a constant temperature coefficient which is independent of the chemical constitution; and, finally (3) no temperature coefficient or a small positive one.[19]

From these results it is to be concluded that the variation of the viscosity with pressure, as observed in the case of anisotropic liquids, does not depend upon the presence of "swarms."[20]

This variation of viscosity and pressure is common to all liquids; the criterion seems to lie wholly in the Poiseuille flow in which the temperature coefficient of viscosity depends upon the chemical constitution.

MOLECULAR SURFACE ENERGY.

We have seen that Bose's theory leads to the conception that an anisotropic liquid is in a state of association, and that it gradually becomes dissociated as the transition temperature is approached, because the molecular swarms become smaller.

Now if MV be the molecular volume of a liquid $(MV)^{2/3}$ will represent an area over which an equal number of molecules are spread, consequently $\gamma\ (MV)^{2/3}$ is the relative molecular surface energy, where γ is the surface energy per sq. cm.

Eötvös proposed the relation $\gamma\ (MV)^{2/3} = K\ (T - t')$ where T is the critical temperature, and t' the temperature of observation. This relation was subsequently modified to $\gamma\ (MV)^{2/3} = K\ (t - \delta)$ where δ is the intercept on the temperature axis obtained by plotting the former relation, which was found to be a linear function of t' up to about 6° from T.

This relation gives for the constant K the value of 2.12 erg/deg. for an unassociated liquid, that is, a liquid in which there are no molecular complexes. Hence $\frac{d}{dt}\left[\gamma(MV)^{2/3}\right] = 2.12$ erg/deg. for unassociated liquids; but if the liquid becomes associated or dissociated, Eötvös assumed that then MV will no longer represent the molecular volume, but $\frac{MV}{x}$ where x is the degree of association. That is, $\frac{d}{dt}\left[\gamma\frac{(MV)^{2/3}}{x}\right] = K$ erg/deg. and thus $x^{2/3} = \frac{2.12}{K}$ or $x = \frac{(2.12)^{3/2}}{K}$. We may write $\mu \equiv \gamma\frac{(MV)^{2/3}}{x}$

Eötvös pointed out that a smaller value than the normal indicates an association, whereas a larger value than the normal indicates a dissociation of the liquid.

The recent work of Jaeger and Kahn [21] on the two phases of anisotropic liquids clearly shows that the (μt) curves correspond to the two cases: "They show *two* branches, of which the first has regard to the anisotropic region, the second the isotropic liquid phase, and in all cases without exception, the first branch falls with an increase of temperature more rapidly than the second branch." From these observations the authors conclude that the theory of Eötvös does not hold for these substances. "According to Bose's theory one would expect an association in the anisotropic phase, on account of the (molecular) swarms, and a large dissociation factor in the isotropic phase when the swarms are broken up: Experiment, however, gives just the very opposite result."

MAGNETIC EFFECTS.

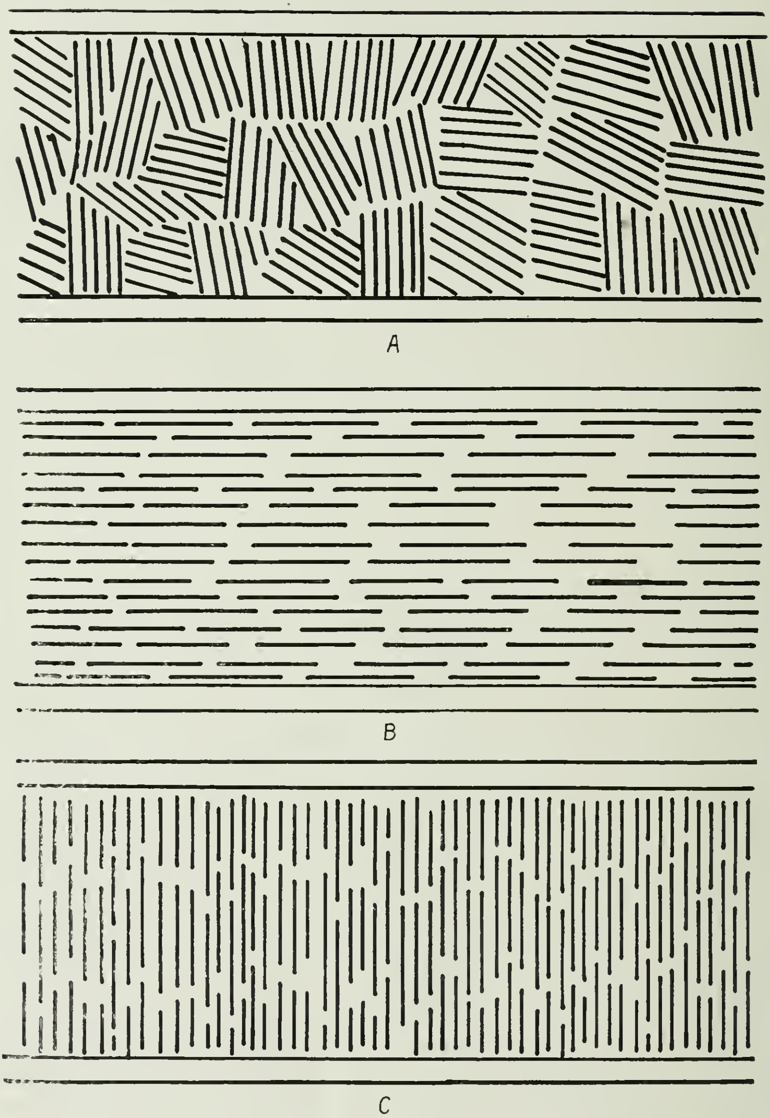
In 1900 O. Lehmann discovered that several anisotropic liquids are influenced by a magnetic field, in such a way that the molecules, or swarms, are orientated so as to lie with their optic axes along the lines of force, so much so that a turbid anisotropic liquid becomes optically homogeneous [22] (Fig. 4).

Bose and others confirmed Lehmann's observations, both for mixtures containing oil, etc., and also for chemically pure substances.[23]

W. Nernst draws the conclusion that this magnetic phenomenon is a crucial test between the rival theories of Bose and Lehmann, and that it is to be considered as evidence against Lehmann's contentions.[24]

In order to test Bose's "theory of swarms," Neufeld used substances whose swarms could be orientated in a magnetic field, so that the long axes, *i.e.*, optic axes, lie along the lines of force.[25]

FIG. 4.



A, no magnetic field; *B*, magnetic field perpendicular to glass plate, according to Lehmann *C*, magnetic field perpendicular to glass plate, according to Bose.

On Vorländer's concept the optic axis is in some cases at right angles to the long axis of the molecules. In such cases the long axis places itself perpendicular to the lines of force.

On letting the substance flow through a capillary tube, placed perpendicularly to the lines of force, one would expect a slower rate of efflux—in the domain for which Poiseuille's equation holds good—when the magnetic field is "on," on account of the internal friction due to the turning effect on the swarms and their breaking up; moreover, *one would expect a quicker efflux just above the transition point*—isotropic phase—in the strong magnetic field *than just below the transition point.* His experiments clearly show that there is no difference in the rate of efflux whether the molecular "swarms" axes are perpendicular or parallel to the sides of the capillary tube; that is, the magnetic field has no influence whatsoever on the rate of efflux, whether the liquid be in the anisotropic or isotropic phase; moreover,[26] he also showed that the pressure efflux is independent of the diameter of the capillary tube.

Consequently we conclude that the magnetic phenomenon does not give any evidence in favor of Bose's theory.

OTTO LEHMANN'S THEORY.

We have seen that a crystal is defined as a solid body in which the atoms are grouped according to some geometrical configuration of centres of force, and that this statement is supported both by the empirically observed laws of crystallography, and by the optical properties of crystals.

According to Lehmann, a crystal should be defined as an *anisotropic body which is endowed with the property of growth,* whether such a body be a liquid or a solid.[27] The anisotrophy of such a body does not necessarily imply optical anisotrophy, but it always does imply what we may call "polarity" with regard to the method of growth, and thus includes biological processes.[28]

The essential difference between this definition and that of crystallography is that the latter defines crystals as having a space-lattice. Lehmann's definition excludes isotropic bodies which have become optically anisotropic under the influence of external forces —e.g., glass in a magnetic field, certain gases in an electric field, and also optically active solutions. If, however, an isotropic body becomes anisotropic under certain conditions, and *if it be also* *endowed with the property of growth* under those conditions, then according to Lehmann, it is a crystal, whether it possesses a space-lattice or not.

It is in this sense that Lehmann used the term "liquid crystal." He maintains that liquid crystals possess a space-lattice only when they are polyhedral in form, similar to solid polyhedral crystals, or when a very thin layer of the crystalline liquid is placed between similar crystalline plates, so that each of the plates has the same orientating effect on the molecules of the liquid.[29] If, however, the solution be placed between amorphous plates, or dissimilar crystalline plates, the solution becomes pseudoisotropic.[30]

The anisotropic properties of a body are, according to his theory, not dependent upon the structure of a space-lattice, but specifically upon the anisotropic properties of the molecules themselves, so that "if the molecules be irregularly orientated, even when they occupy the points in a regular lattice, such a body would not display anisotropic properties." [31]

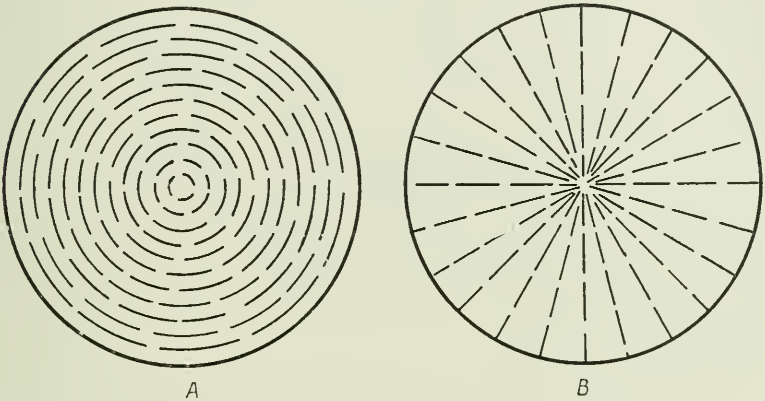
Moreover, he maintains that a change in the space-lattice of a crystal is not accomplished by any change in the vapor pressure, melting-point, and solubility of the crystal. Where changes in the physical properties do take place, they are attributed by him to a change in the structure of the molecules themselves.[32] This is essentially the difference between the theories of Bose and of Lehmann.

These conceptions of Lehmann, which he explained fully in numerous works,[33] are in direct contradiction to the theory of the identity of molecules in the so-called three states of matter, so much so that Nernst [34] denies the existence of liquid crystals.

We have seen that Bose, on the evidence of Vorländer's chemical researches, assumed that the molecules are ellipsoidal; Lehmann initially assumed that the molecules were spindle-shaped, but on the evidence of his later researches, he rejected this form and assumed a lamellar structure for the molecules. Lehmann's evidence is founded on the following argument (Fig. 5; see *A* and *B*).

In the case of carefully cleaned glass plates,[35] the molecules which form the pseudoisotropic layers set themselves in a definite direction with regard to the glass surface. In this condition the liquid behaves optically like a uniaxial crystal, with its axis perpendicular to the surface. Now when the liquid is placed in a glass tube and if it be allowed to flow out, the optical properties will indicate how the molecules are placed with regard to the glass walls. On examining the optical properties under these conditions, he found that the molecules are placed with respect to the glass walls of the tube exactly as they were in the case of cover slides. From this phenomenon he concludes that the molecules cannot be spindles standing normally to the glass walls, because then a turning moment, due to variation of the velocity from the centre to the side of the tube, would rotate those molecules which are near the walls of the tube, and thus change the optical phenomenon; hence he decides that the molecules must be "leaflets," whose magnetic and optic axes are normal to their surface. The evidences now reviewed clearly show:

FIG. 5.



(I) The magnitude of Bose's swarms must be reduced in order to agree with the observations on the rates of efflux through narrow capillary tubes.[36]

(II) Either Eötvös' theory must be modified so as to include anisotropic liquids or Bose's theory must be dropped. Lehmann's theory, however, deals with molecules, and he considers physical changes in the constitution of the molecule itself responsible not only for polymorphism but also for association and dissociation.

The sole reason why Bose's theory is preferred by some to Lehmann's is simply because "it is in harmony with the treasured theories of molecular physics" and at the same time gives an explanation of the phenomenon of anisotropic liquids.

D. VORLÄNDER'S THEORY.

We have seen that Bose and Lehmann do not classify anisotropic liquids under the same heading as the generally accepted definition of solid crystals. Vorländer, however, contends that anisotropic liquids are in reality solid uniaxial crystals, whose elastic constants are small, that is, there is still a small cohesion between the component parts of the space-lattice.[37] According to him, all anisotropic liquids are in reality uniaxial crystals, even though they are derived from the most complex organic compounds. This assertion is far-reaching, because complex organic compounds generally give rise to optically biaxial crystals. Moreover, he asserted that the so-called pseudoisotropic layers—which term he calls " mystisch "—are uniaxial crystals, and that this statement is confirmed by his observations on the optical properties, when he had examined such layers in convergent polarized light.[38]

Now if these pseudoisotropic layers, or the globules, be uniaxial crystals, then when such liquid crystals solidify or grow, they should form squares or hexagons because tetragonal and hexagonal crystals are uniaxial. He contended that under favorable conditions, according to his observations, liquid crystals develop these shapes approximately, while still liquid, with edges approximately straight.[39]

Friedel and Granjean, however, clearly showed, subsequently, that these phenomena were due to a linear aggregation of globules and were caused by the apposition of two or more individual crystals, and that there is no geometrical similarity to the forms obtained in the case of solid crystals.[40] In our introduction we gave considerable space to the optical properties of crystalline solids, and showed that crystals may be divided into three main types according to their optical properties. Thus:

Cubic crystals are optically isotropic,
Hexagonal and Tetragonal crystals are optically uniaxial,
Orthorhombic, Monoclinic and Amorthic crystals are optically biaxial.

Now the converse argument that double refraction is due to crystal structure, hence anisotropic liquids are crystals, is not necessarily true because gases under certain conditions are doubly refracting, and crystalline structure cannot be attributed to gases.

Double refraction and dichroism, or plechroism, only indicate polarity of structure, which structure is not necessarily crystalline.

We may only attribute crystalline structure to gases in an electric field, and to liquids in a magnetic field as well as to optically active solutions, if we accept the theory that the molecules under all conditions are themselves crystalline in nature, and that their lattices may be similarly arranged by the application of external mechanical forces as well as by chemical affinity. The molecules thus which give rise to optical anisotropy must themselves be "polytropic" in nature. Growth will then only take place when the translatory motion is reduced to zero so that the component atoms only may continue to oscillate about their centres of equilibrium.

RÖNTGEN RAYS AND CRYSTAL STRUCTURE.

It will be seen that Bose and Lehmann on one hand deny that pseudoisotropic liquids have a space-lattice, whereas Vorländer definitely states that they are uniaxial crystals even though the forms are doubtful and their elasticities vanishingly small. The latter's theory cannot be put to the usual mechanical tests for elasticity, cleavage or cohesion, hence it was desirable that a crucial experiment should be devised to determine which of the two structures answered to the facts, and for this purpose Laue's recently devised method by X-ray research seemed excellently suited.

X-RAYS AND CRYSTAL STRUCTURE.

In the next paragraph we give a short summary of the method with special reference to the point at issue.

Until recently the theory of crystallography was supported principally by the analogy between crystal structure, polymorphism, and the morphotropic relations of various compounds, and the law of zones, rational indices, etc.; but there was no direct proof to show that the units of a crystal were actually arranged in a definite space-lattice. Microscopically this is impossible, because the shortest wave-length of visible light is only of the order 10^{-5} cm., whereas the atoms are of the order 10^{-8} cm. Under these conditions a crystal will act as a continuous medium for ordinary light, because the rays will not suffer diffraction because of the smallness of the atoms in comparison with the wave-length of light.

After his discovery of X-rays, Röntgen tried to find some optical relations between these radiations and ordinary light. He was only successful in so far that he showed that their intensity follows the inverse square law; he could not, however, find any reflection or refraction.

Haga and Wind attempted to find a diffraction effect by passing these rays through a V-shaped slit. From their observations they concluded that the wave-length must be of the order 10^{-8} cm. Walter and Pohl, however, concluded that this method leads to the value 10^{-9} cm.

Subsequently Sommerfeld and Koch, independently, arrived at the conclusion that the quanta theory of Planck leads to the value 10^{-9} cm.

Now we see that crystallography and molecular physics affirm that the atoms or molecules are grouped according to some definite geometrical configuration of points, which form the space-lattices of crystals, and that the linear dimensions of atoms are of the order 10^{-8} cm. On the other hand, experiment and Planck's Radiation theory show that the wave-length of X-rays must be of the order 10^{-8} or 10^{-9} cm., *i.e.,* the probable wave-length is comparable to the dimensions of an atom or molecule in a regular space-lattice. To this must be added the evidence that Sagnac and Barkla showed that X-rays are scattered by solids.

These contentions led Max Laue to consider the crystal as an excellent three-dimensional diffraction grating for X-rays.[41]

The constants of this grating will thus, if they be known, give a mathematical expression of the positions of the directions along which the radiations diffracted from the atoms will reinforce each other. His anticipations were fully justified by the epoch-making experiments carried out by Friedrich and Knipping.

Since the publication of these results, numerous experiments have confirmed them; and the X-ray spectrum was soon mapped out as a particular region in the spectra of electromagnetic waves, and at the same time lattices of crystals were unravelled. The configuration of these loci of maximum intensity which may be recorded on a photographic plate is determined by the direction of transmission of the rays through the crystal, and naturally by the type of grouping of the atoms in the space-lattice of the crystal.[42]

a. Point patterns, that is, patterns of points lying on conic sections.

b. Radial line patterns. These consist of lines radiating out from the central point, which point is due to direct transmission.

c. Ring patterns. These consist of zones whose intensity is constant for certain values of the radius drawn from the central point.

d. Patterns consisting of small irregularly shaped spots and broken lines.

The patterns under *a* are due to the projection of the diffracted cylindrical pencils—or small cones of rays in the case where the incident radiations are not parallel—on the plane of the photographic plate. These points are regular images of the openings in the diaphragm, provided that the crystal covers the whole of the opening, and this type of pattern indicates a regular space-lattice,[44] whereas the radial line patterns show that there is a transition grating, that is, the third elastic constant of the crystal is changing.[45]

The ring or zone pattern indicates that the crystal is made up of smaller crystals in which *one axis* is fixed in space. If an axis be placed normally through the central point of a symmetrical pattern of type (*a*), and if this be rotated round this axis, the equidistant points will trace out a zone of uniform intensity. The same effect will be produced if the crystals be rotated round the axis along which the incident rays travel.[46]

Patterns under *d* are due to irregularly orientated elements which constitute a microcrystalline body. Here the spots are images of the individual crystals which are covered by the incident pencil. The size of the diaphragm does not affect the size of these singularly distributed spots.[47]

Now it will be seen readily that when Röntgen rays are transmitted through a body and the emergent rays are recorded on a photographic plate, the pattern will indicate the nature of the architecture of the body, especially will it show whether a body be truly amorphous or crystalline.

OBJECT OF RESEARCH.

The object of our experiment was to find whether the pseudoisotropic layers of Lehmann and Bose have a space-lattice according to the contentions of Vorländer.

SELECTION OF SUBSTANCE.

The substances which we selected for this work were:

A. p. azoxyanisole
B. p. azoxyphenetole
C. anisaldazine
D. p. "cyanbenzalaminozimt-saure-akt-amylester"
or
"Slumpf's Cyanester."

The first three substances were taken because their molecules of "swarms" may be orientated in a magnetic field so that their principal or magnetic axis lies either along or perpendicular to the lines of force, and they are such that, when viewed along the lines, and normal to the lines, they display regular anisotropic properties of solid crystals, the phenomena being those generally associated with a uniaxial crystal cut normal and parallel to the optic axis respectively.[48]

This magnetic effect enables one to fix one axis in space, and thus the nature of the emergent Röntgen rays will determine whether the subordinate axes are also fixed in space, or whether they are, contrary to Vorländer's theory, but according to Lehmann and Bose, distributed at random.

"Stumpf's Cyanester" was used at the conclusion of our experiments because its refractive indices had been determined very accurately.[49]

APPARATUS.

In order to heat these substances to a fixed temperature, a pair of copper spirals were constructed out of two copper cones and four copper plates.

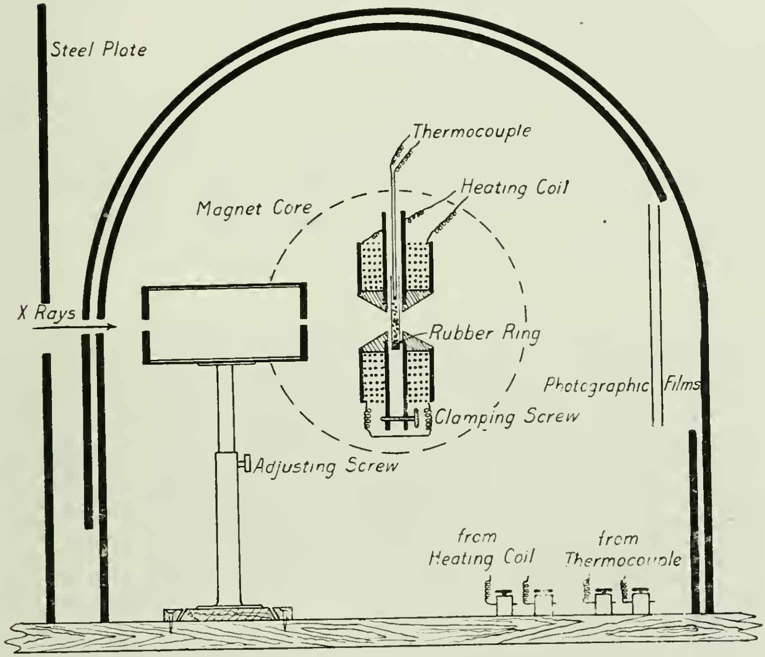
As these substances had to be placed in a magnetic field, equal lengths of copper wire were wound round the cones, so that the current passed in opposite directions round them. This avoided the turning moment of the magnetic field on the spirals as well as an extra orientating effect on the molecules of the anisotropic liquids.

Between these spirals the substance experimented on is enclosed between two thin glass plates, which are kept in position by means of the three screws which clamp the spirals together.

The temperature of the substance between the glass plates was determined by a sensitive thermocouple. A good microscope, fitted for crystallographic work, was clamped to the midpoint of a flat piece of brass, whose ends were attached to semicircular flat pieces of brass.

The under side of these flat semicircular pieces, which rested on the coils of the electro-magnet and thus carried the weight of the microscope, was lined with thick velvet, so as to protect the insulation of the coils. When this holder was placed over the coils, the pole pieces of the electro-magnet were between the objective and the object table of the microscope, consequently the solution, which was placed between the pole pieces, could be examined without any difficulty.

FIG. 6.



Before the heating spirals were clamped in position, pads of wadding were glued to the pole pieces of the electro-magnet in order to minimize heating effects. Lead jackets were constructed so as to cover the whole of the electro-magnet.

In order to protect the X-ray tube a slab of soft iron was interposed between it and the electro-magnet. A narrow beam of X-rays was obtained by using a lead diaphragm similar to that originally used by Friedrich and Knipping.

Fig. 6 gives a section through the apparatus and shows the course of the X-ray, through the substance under investigation, to the films. Fig. 7 shows the electrical connections, and the photograph shows the apparatus—together with the microscope and its holder—immediately before an exposure (photo).

FIG. 7.

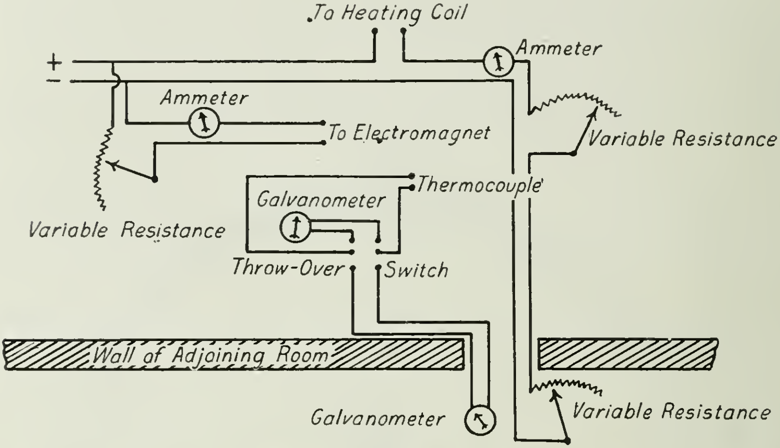
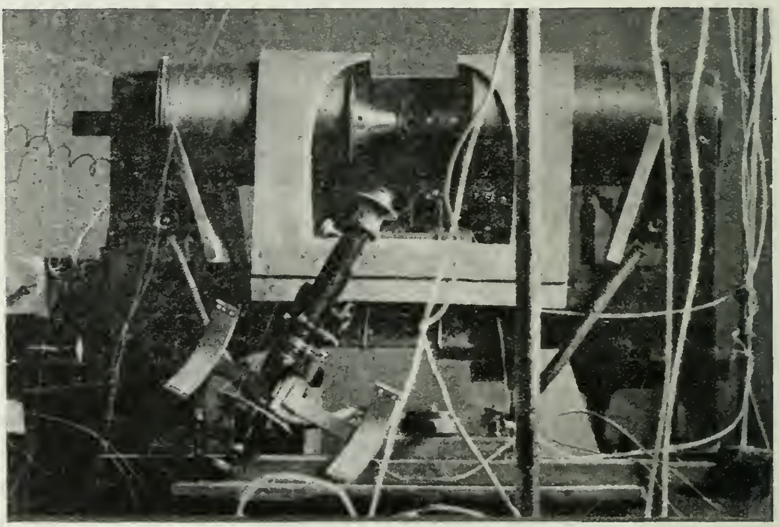


FIG. 8.



Apparatus ready for exposure.

METHOD OF EXPERIMENT.

The field strengths of the electro-magnet when the spirals were between the poles were determined by means of a standard bismuth spiral.

These values were recorded for a series of different current strength which were read off from an ammeter. Next, the deflections of the galvanometer were recorded for a range of temperatures of the hot junction of the thermocouple (iron-constantan). This hot junction was placed in an oil bath alongside of a standard 1/10° thermometer; the cold junction was kept in a funnel of melting ice.

A rubber ring 1 cm. in diameter was cut at a point and placed on a coverslip, which had been cleaned in H_2SO_4, hot water and finally dipped in ether and left to dry. A small quantity of the substance to be experimented upon was carefully powdered and placed inside this cut ring, and was covered with a similarly prepared glass plate. The size of the plates was: 0.17 mm. thick and 11 mm. square. This slide was carefully placed between the spirals so that the cut in the ring was uppermost.

The junction of the thermocouple was then placed in position and the spirals clamped between the padded pole pieces. A current was passed through the spirals and the microscope was focussed on the substance. On melting, air bubbles were expelled through the opening in the ring by gently screwing and unscrewing the spirals. Subsequently this method was modified as follows: Instead of the rubber rings, clean flat pieces of rubber were used. These pieces of rubber were cut so as to have an 8 mm. circular opening in the centre. This circular opening was then joined by a 1 mm. canal. This canal then contained the junction of the thermocouple.

RÖNTGEN RAYS AND ANISOTROPIC LIQUIDS.

Pseudoisotropic Layers.

Parazoxyanisole.—A slide of this substance was prepared as described above. After careful microscopic examination in a field of 5000 Gauss, it was heated from 118° to 136°, where it became amorphous, and allowed to cool gradually in the magnetic field.

After it had solidified, the diaphragm was placed in front of the slide in line with the focal spot of the anticathode of the tube.

This was done by focussing a cathetometer on the focal spot and moving the tube until the focal spot was midway between the poles of the electro-magnet and on the cross hairs of the telescope—during this process the spirals were removed.

The diaphragm was then illuminated from the tube side and was placed so that its openings were in line with the cross hairs and the focal spot. Next the slide was placed in position by centring its openings, and rotating it until the light from a pea lamp, attached in front of the telescope, was reflected back from the glass plates into the telescope. At a distance of 3.5 cm. behind the spirals, two sensitive X-ray films were placed. The first layer of lead and the magnetic screen were then placed in position, and the X-rays were transmitted through the diaphragm and the slide. This transmission was tested by placing a screen behind the window. After these preliminary observations had been made, the outer jacket was put over the electro-magnet. The objects of this experiment were to find whether the glass plates absorbed the diffracted rays from the thin layer of solid crystal, and also whether the substance crystallized into a homogeneous crystalline plate under the action of the magnetic field. After an exposure of four hours, the first film was developed, and it showed that the plate was crystalline, but not homogeneous, that is, it became microcrystalline on solidification, hence this layer which appeared optically homogeneous in the magnetic field became microcrystalline on solidification.

The second film was developed after an exposure of eight hours. This film, which was used as a check on the first, to eliminate film flaws, showed the same pattern of the fourth type, and also a large amount of dispersion.

On removing the slide, and examining it microscopically, the optical irregularity could be seen only slightly by rotating the slide between crossed nicols.

These results, like our preliminary ones, show that the molecules or " swarms of molecules " do not retain their orientation and secondly, that the glass plate does not absorb the diffracted rays to such an extent that a photogram cannot be obtained.

This slide measured about 0.3 mm.

A slide of the same substance 0.5 mm. thick was prepared and heated up to 118° C. It was carefully observed by means of the microscope to ensure that the layer was optically homogeneous.

The temperature was kept constant by observing the deflection of the galvanometer, and if necessary regulating the resistance in circuit.

The diaphragms, films, lead jackets and magnetic screen were placed in position and the exposure commenced.

RECORD OF RESULTS.

Paraazoxyanisole.

Thickness of Layer.	Magnetic Field.	Time of Exposure.	Nature of Photogram.
.05 cm.	5000 Gauss	8 hours	Only dispersion.
.05 cm.	5000 Gauss	16 hours	Increase in dispersion.
.03 cm.	5000 Gauss	15 hours	Dispersion.
.07 cm.	5000 Gauss	15 hours	Dispersion.

Temperature 118° C.

The same method of experimenting was used in the case of *Paraazoxyphentole.*

Thickness of Layer.	Magnetic Field.	Time of Exposure.	Nature of Photogram.
.03 cm.	5000 Gauss	15 hours	Dispersion.
.05 cm.	5000 Gauss	15 hours	Dispersion.
.07 cm.	5000 Gauss	15 hours	Dispersion.

Temperaure 140° C.

Anisaldazine.

A with a trace of olive oil; *B* pure.

A. 0.5 mm. thick in a field of 5000 Gauss. Time 10 hours. Dispersion.
B. 0.3 mm. thick in a field of 5000 Gauss. Time 9½ hours. Dispersion.

On account of the high temperature, 172° C., this substance caused a lot of trouble. Several experiments of shorter duration than *B* were interrupted on account of the insulation of the spirals giving way.

"CYANESTER OF STUMPF."

This substance was prepared for me in three degrees of purity *A, B, C* by Professor Werner, to whom we wish here to express our thanks. *C* was chemically pure. Layer of 1/10 mm. in the solid state gave no interference pattern, but layers of .2 gave patterns of a microcrystalline nature. An anisotropic layer of *A* showed no interference phenomena after an exposure of twelve hours—no magnetic field on. A similar layer of *C* gave the same result after an exposure of ten hours, at which stage we were forced to discontinue our investigations.

CONCLUSION.

These results clearly and definitely show that the pseudoisotropic layers of Lehmann and Bose do not possess homogeneity of structure as this term is understood in crystallography, nor is there any evidence to show that such layers are microcrystalline. Consequently we conclude that the above experiments show that such layers of anisotropic liquids do not possess a space-lattice; that is, the contention of Vorländer, based on the optical phenomena of such layers, cannot be accepted.

The uniform dispersion which was observed in each case is not due to the glass plates, as the author initially thought,[52] but is wholly due to the regularity of molecular structure of these anisotropic liquids, probably caused by similarly orientated ellipsoids one of whose axes only is fixed in space.

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[1] See Ch. 20 Neue Welt d. Flüssigen Kristalle, 1911. *Ann. d. Phys.*, 40, 401; **41**, 525, 1890. *Ann. d. Phys.* (4), **2**, 649, 1900.

[2] *Ann. d. Phys.* (4), **4**, 524, 1901.

[3] *Phys. Zeit.*, **8**, 347, 1907. Bose defends Tamman's theory against Schenck and Eichwald, who contend that there is a sudden transition from anisotropic liquid to isotropic liquid, and that this phenomenon is not shown by emulsions.

[4] *Phys. Zeit.*, **8**, 513, 1907. Reviews the emulsion theory and "without wishing to enter the fight about liquid crystals" merely suggests his theory of swarms.

[5] *Ber. d. Chem. Gesell.*, 40, 1970, 1907; **41**, 2035, 1908, etc.

[6] *Phys. Zeit.*, 10, 230, 1909, for full theory.

[7] *Phys. Zeit.*, 9, 169, 1908, conjointly with Conrat.

[8] *Phys. Zeit.*, 9, 707, 1908. This discovery made Bose give up the emulsion theory.

[9] *Phys. Zeit.*, **8**, 42, 1907. (Lehmann's questions concerning "Emulsions.")

[10] *Phys. Zeit.*, 10, 32, 1908.

[11] *Phys. Zeit.*, 10, 230, 1909.

[13] *Phys. Zeit.*, 10, 244, 1909.

[13] DR. ING: Dissertation, Danzig, 1913. These researches were suggested by Bose, but were carried out under Kruger. Here we may say that Bose was the prime factor for inspiring young men to carry out researches on his viscosity anomaly. He, Bose, left Danzig to take up duties at La Plata, where he supervised the building of his laboratory. He met Professor W. Sorkau and inspired him to carry on his researches. (See Bose and Lauert, *Phys. Zeit.*, 10, 406, 1909), on the anomaly for pure liquids. The published results of Sorkau, who carried out the work in Bose's laboratory, were not seen in print by Bose, who, in the prime of his life and exceptionally brilliant activities, was laid to rest on the 25th day of May, 1911.

[14] *Phys. Zeit.*, 10, 32, 1908.

[15] *Phys. Zeit.*, 10, 406, 1909. Conjointly with Rauert. (Paper was sent from Lissabon—Bose was on his way to La Plata; see 4.)

[16] *Phys. Zeit.*, **12**, 582, 1911; **13**, 805, 1912.

[17] See MIE, *Phys. Zeit.*, **14**, 93, 1913.

[18] SMILES: "The Relation Between Chemical Constitution and Some Physical Properties." Ramsay Series, 1910.

[19] SCHAEFER and FRANKENBERG: *Phys. Zeit.*, **14**, 89, 1913.

[20] *Phys. Zeit.*, **15**, 582, 1914. Sorkau says: "Die Graphischen Darstellung im logarithmischen Druck Geschwindigkeits-Koordinatensystem, lehren dass zwei Strömungsarten zu unterscheiden sind." He does not accept the small positive value given by Schaefer and Frankenberg. Equations deduced from his students' observations are: Poiseuille's equation $P\,T = K$ where P is the pressure and T the time of efflux for a given volume; K, a constant depending on the chemical constitution, the length of the tube, and the fourth power of the radius. Turbidity types:

First $P^{0.55}\ Te^{\theta/273} = K_h$ Called Hagen's flow by Sorkau. $\theta =$ the temperature of the liquid.

Second $P^{0.65}\ T = K_f$ Called the Frictionless flow.

In Type 1 K depends on the dimensions of the tube in the same way as K in the Poiseuille flow.

In Type 2 the liquid flows out like a solid mass, whose radius is smaller than that of the tube, which is bounded by an immovable cylindrical layer of liquid. The thickness of this "Lot-wasserschicht" also varies directly as the length of the tube.

[21] *Proc. Kgl. Akad. d. Wetchsch.*, Amsterdam, Vol. 18, pt. 1, 297.

Substance: p. azoxyanisole.

$\frac{d\mu}{dt} = 7.1$ erg/deg. between 115 C and 126 C. Anisotropic phase.

$\frac{d\mu}{dt} = 12.2$ erg/deg. between 126 C and 133 C.

$\frac{d\mu}{dt} = 3.45$ erg/deg. to 2.2 erg/deg. at 190° C. Isotropic phase.

p. azoxyphenetole:

$\frac{d\mu}{dt} = 6.6$ to 4.89 erg/deg. between 143 C and 164 C. Anisotropic phase.

$\frac{d\mu}{dt} = 2.68$ erg/deg. Isotropic phase.

Anisaldazine.

$\frac{d\mu}{dt} = 11.0$, 15.2, and even 19.3 erg/deg. Anisotropic phase.

$\frac{d\mu}{dt} = 3.27$, to 1.53 erg/deg. Isotropic phase.

(The fourth substance showed a decrease up to a certain point, followed by gradual increase. This is due probably to a second anisotropic phase.)

[22] *Ann. d. Phys.*, **2**, 676, 1900. Substances used with a trace of oil, peperin, etc. p. azoxyanisole, p. azoxyphenetole, anisaldazine.

[23] BOSE: *Phys. Zeit.*, **10**, 241, 1909; 12, 60, 1911. Ch. Manguin, *Comph. Rendus*, **152**, 1680, 1911, etc.

[24] *Zeit. f. Elektro. Chem.*, 16, 702, 1910. See also *Theor. Chem. Ta:f.*, 3666. Cf. v. WARTENBERG: *Phys. Zeit.*, 12, 837, 1911. Wartenberg, in spite of the fact that he rejects Lehmann's theory, had to admit that this phenomenon does not furnish any evidence against Lehmann's theory.

[25] *Phys. Zeit.*, 14, 646, 1913. Substances: p. azoxyanisole, p. azoxyphenetole, and anisaldazine.

[26] Dissertation, DANZIG: When the diameter of the tube is comparable with the magnitude of the swarms the efflux ought to be comparatively slower than when it is large in comparison with the size of the swarms. The flow ought to be slower for small capillaries than that given by Poiseuille's equation. $\frac{P\pi TR^4}{8L\eta} =$ volume discharged in time T under a pressure P, in a tube of radius R, and length L when η is the viscosity of the liquid at a given temperature.

[27] *Phys. Zeit.*, 8, 42, 1907, etc.

[28] *E.g., Biochem. Zeit.*, 63, 1, 74, 1914.

[29] *Ann. d. Phys.*, 39, 80, 1912.

[30] *Phys. Zeit.*, 14, 1129, 1913.

[31] *E.g., Phys. Zeit.*, 14, 2, 1913.

[32] Molekular theorien, Vol. 2, page 413, 1889. Flüssige Kristalle, 164, 1904.

[33] See Verzeichnis sämtlicher Veröffentlichungen von O. Lehmann. Fr. Vieweg and Sohn. Braunschweig.

[34] See (25) *Theo. Chem.*, 7 Ed., 666.

[35] Method of Manguin, *Phys. Zeit.*, 12, 1013, 1911. Hot sulphuric acid and subsequently washed in ether and distilled water.

[36] Neufeld's work showed conclusively that the pressure-velocity variation in the Poiseuille state of flow remains constant for different sized capillary tubes. This is in accordance with Lehmann's conception of lamellar anisotropic molecules, but it is not in accordance with Bose's "swarms" unless these swarms are of molecular dimensions or very much smaller than Bose's estimate.

[37] *Phys. Zeit.*, 15, 141, 1914.

[38] *Zeit. Phys. Chem.*, 61, 166, 1907; *Acta Nova*, 90, 1909. C.f. *Phys. Zeit.*, 11, 177, 1910.

[39] Vorländer: "Flüssige Kristalle," p. 22; *Zeit. Chem.*, 57, 363, 1906.

[40] *Bull. Soc. France Min*, 33, 192, 409, 466, 1910. *Compt. Rendus*, 151, 442, 1910.

[41] For development see von Laue, "Festschrift der Dozenten," Zurich, 1913, and Bragg, "X-rays and Crystal Structures," 2d Ed.

[42] T. TERADA: *Tokyo Math.-Phys. Soc.*, 7, 60, 1913, for visual shift of points due to a rotation of the crystal.

[43] The incident rays are in all cases supposed to pass through a circular diaphragm.

[44] *E.g.*, LAUE: "Festschrift d. Dozenten," Zurich.

[45] FRIEDRICH: *Phys. Zeit.*, 14, 1079, 1913. M. v. LAUE and J. STEPH. V. D. LINGEN: *Die nat. Wissensch.*, 13, 1914. In the case of burcite the author has shown that this phenomenon is due to driving off water molecules, and that the crystal then behaves as if the C' axis becomes elongated. On account of the fact that C' is not constant for crystals, the points proceed and

recede—from layer to layer—from the central spot so that the radial line gives the intensity of the spectrum.

[46] See *Phys. Zeit.*, 14, 1079, 1913. *Tokyo Math.-Phys. Soc.*, 7, 60, 1913.

[47] *E.g.*, HUPKA: *Phys. Zeit.*, 14, 623, 1913. O. LEHMANN: *Ann. d. Phys.*, 2, 676, 1900, etc.

[48] E. BOSE: *Phys. Zeit.*, 12, 60, 1911. A. v. WARTENBERG: *Phys. Zeit.*, 12, 837, 1911, etc., etc.

[49] Dissertation, Göttingen; or, *Ann. d. Phys.*, 37, 397, 1912.

[50] The flat pieces of rubber have this advantage, that they distribute the pressure evenly over the glass plates; moreover, their thickness could be regulated better than those of the ring.

[51] "Molekulare Bau Flüssiger Kristalle," 1913. Subsequent experiments with crystals mounted on glass showed that this effect is not given by glass plates.

[52] *Verh. d. Deutsch Phys. Ges.*, 18/19, 1913.

Double Refraction and Crystalline Structure of Silica Glass. LORD RAYLEIGH. (*Proc. Royal Society,* No. A. 692.)—Ordinary glass is not doubly refracting except when under stress. In contradistinction to this the experimenter found that silica glass, produced by the melting of clear, cyrstalline quartz, does have double refraction, though it is only to the extent of one-sixtieth of that of crystalline quartz. When examined by nicol prisms the glass shows a granular structure, possibly due to the pieces of silica melted together to form the piece under examination. Optical silica, built up by a special process, presented, when placed between crossed nicols, an appearance resembling the interference figure of a uniaxial crystal in convergent light. Specimens of this glass were heated to red heat over a period of two hours and were then quenched in water. Contrary to expectation, a network of cracks appeared on the surface. After the surface had been repolished examination with the nicols showed no trace of the former pattern. Reheating for ten minutes caused the reappearance of pattern.

G. F. S.

Combined Developing and Fixing. (*Photographic Jour. of America,* March, 1921, p. 124.)—French photographers seem to be especially interested in bizarre processes, and among these have investigated the methods by which the developing and fixing agents are combined in one solution. They have also given attention to processes in which fixation precedes development, a curious and interesting reversal of the usual method, and one that has been but little considered by the writers on the latent image. Lumière Brothers and Seyewetz have been especially active in researches along this line, and in a recent communication to the French Society of Photography

(*Bull. Soc. Franc. d. Phot.*, November, 1920, reprinted in *Photo-Revue*, 1921, 5) give some new methods for using combined baths. After a review of the literature and pointing out some unsatisfactory methods, they give two solutions which they claim will give good results. These are:

FORMULA No. 1.

Water	1000 c.c.
Sodium sulphite	32 grm.
Chloranol	6 grm.
Sodium hydroxide	5 grm.
Hypo	60 grm.

FORMULA No. 2.

Water	1000 c.c.
Sodium sulphite	32 grm.
Metoquinone	6 grm.
Tribasic sodium phosphate	100 grm.
Hypo	40 grm.

The sodium sulphite is the ordinary anhydrous form. The sodium phosphate is the one in which all the hydrogen of the acid is replaced, being Na_3PO_4, and not the common form sold in drug stores. In formula No. 1 the sodium hydroxide can be replaced by 140 grm. of the tribasic phosphate and the hypo reduced to 48 grm.

The writers claim that these formulæ will give negatives of entirely satisfactory character, and are especially applicable to cases of over-exposure. The duration of the process is from twenty to twenty-five minutes and is automatic, taking place equally well with vertical or horizontal position of the plate. Papers require only about two minutes. They also claim that the procedure does not require a special method of illuminating the room in which the operation is conducted. A greater or less duration of the process does not imperil the value of the negative.

Metoquinone is stated to be composed of two molecular weights of methyl-paraminophenol and one molecular weight of hydroquinone; chloranol is composed of two molecular weights of methyl-paraminophenol and one molecular weight of chlorhydroquinone. Both these substances share with paraminophenol the property of developing without the addition of alkali, but alkali may be added as accelerator.

With chlorbromid papers it is advisable to double the time of exposure, and the action of the bath should not be continued beyond two minutes or the purity of the image will be diminished. Papers containing only silver bromide cannot be developed by these methods, as they become markedly veiled. The addition of potassium bromide does not prevent this action.

A NEW GENERAL LAW OF DEFORMATION.[*]

BY

P. G. NUTTING, Ph.D.

THROUGHOUT the mechanics of elasticity and hydrodynamics frequent use is made of the laws:

I. DEFORMATION PROPORTIONAL TO FORCE APPLIED,

and

II. RATE OF DEFORMATION PROPORTIONAL TO FORCE.

The first of these applies to elastic bodies and is commonly known as Hooke's Law, the second is used in dealing with fluid flow and lacks a specific name though the particular form relating to flow through small tubes is known as Poiseuille's Law.

Hooke's Law is known to hold closely over a considerable range of forces for many solids. Failing to take account of either plastic or viscous yield or any other form of energy dissipation, it applies best to the more nearly perfectly elastic bodies. The viscosity law (II) applies fairly well to many fluids, both highly and but slightly viscous, but not at all well to others. It assumes complete dissipation of the work done in deformation with no elastic storage of energy. Both laws are empirical approximations and must remain so unless they can be deduced from known molecular relations. If one may judge from the literature of the subject, experimentalists have rested in the belief that theoretical work had established the foundation for these laws, while theoretical writers, on the evidence of the experimentalists, have contented themselves with the first term of a Taylor series expansion of an unknown function. Voigt frankly states (Mechanik, 1901, pp. 474 and 495) that the ultimate causes of both elasticity and viscosity are molecular and that the linear relations given rest on the pure assumption that the second order terms are negligible.

In mathematical form, the two laws mentioned, namely:

$$s = kF \tag{1}$$

and

$$s = ktF \tag{2}$$

$$v = ds/dt = kF$$

are at first sight incompatible as applied to the same material. If a steady stress produces a continuous deformation (2) in a homogeneous body, that body cannot possess elastic properties toward the same steady stress and conversely if a body is elastic (1), it is incapable of steady flow. On this basis only heterogeneous bodies are therefore capable of both elastic and viscous deformation under a given stress. The accepted electromagnetic theory of light is based on the assumption of displacements of this nature.

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[*] Communicated by the Author.

Michelson[1] has carefully investigated the yielding of metals and other solids under a torsional shearing stress. In formulating his results he writes for the displacement the sum of four components: (1) lost motion, (2) elastic, (3) elastico-viscous and (4) viscous displacement. The complete expression is extremely complex and involves nine constants. The term representing the "elastico-viscous" displacement (No. 3) is

$$s_3 = c_3 \left(1 - e^{-a} \sqrt{t} \right) F e^{b} F \tag{3}$$

This does not represent our data as well as the much simpler formula given below.

In order to obtain precise data upon which to formulate a law applicable to slowly yielding media, the writer took up the study of deformation in pitchlike substances subjected to pure coplanar shearing stresses. Many such substances are known to possess both elastic and viscous properties in a high degree and it was hoped that the data obtained might throw light on the fundamental principles upon which (I) and (II) are based. The results indicate that each is a special case of a simple general law, a law quite new in mechanics and of extremely wide application. It is empirical, but so are the laws of elasticity and of viscous flow just mentioned. Carrying the analogy over into electrical theory, another general law of electrical conduction is obtained of which Ohm's Law is a special case.

Considerable data by many observers is available for testing deformation formulas. That obtained by the writer is being presented at the 1921 meeting of the American Society for Testing Materials with complete descriptions of instruments and methods employed which need not be repeated here. Suffice it to state that the shear measured was produced between parallel plates 50 x 100 mm. in area, 2 mm. apart. Displacement readings were taken after ten or more time intervals after each force was applied, and for six to ten different forces and usually several different temperatures. One substance was found (a hard stearine pitch) for which the viscosity as ordinarily computed decreased to one-tenth as the force was increased from 1 to 10 kg. Another, although a hard solid (140° hydrolene), showed true viscosity, *i.e.*, the ratio of force per unit area to rate of shear was practically independent of the force applied.

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[1] A. A. Michelson, *Proc. Nat. Acad.*, May, 1917, and March, 1920.

The displacement-time curves were found to be generalized parabolas, s proportional to the n^{th} power of the time t, hence *log* s a linear function of *log* t. Further, n is the same for all forces, the various s–t curves differing only by a constant factor. A similar relation was found to hold in all cases for the displacement-force curves (time constant), *log* s is a linear function *log* F, s being proportional to the m^{th} power of the force F for any constant time without systematic variation.

Our general formula is then

$$s = at^n F^m \tag{4}$$

in which n and m are independent of s, t and F but are functions of the temperature. They are also, of course, independent of the area and thickness of the test piece, independent of the units employed, and also of the method of test so long as it involves only a pure shear. The constant a is independent of s, t and F but depends on the units and method employed.

It is readily seen that the old law of elastic deformation (1) is a special case of (4) for which $n = 0$ and $m = 1$. Also the law of viscous deformation (II) $s = atF$, or $v = aF$ is a special case for which $m = 1$ and $n = 1$. Experimental values of n have been found as low as 0.2 and as high as 0.91 and of m from 0.74 to 3.5. A value of m greater than unity means a plastic yield more than proportional to the force, often of the nature of an internal rupture, while a value less than unity signifies the converse, a consistency resembling quicksand in its nature. All highly fluid liquids of course have n nearly unity, in fact melting might be defined as a temperature at which n has a definite assigned value approaching unity. Similarly a definite low value of n approaching zero might be used to specify the beginning of the solid state.

Alternative forms of the general deformation law (4) may be written

$$\frac{ds}{s}=n\frac{dt}{t}+m\frac{dF}{F} \tag{5}$$

$$s\left(\frac{l}{s}\frac{ds}{dt}\right)^n=(an)^n F^m \tag{6}$$

From (5) it is evident that the error in theoretical work on deformation has been the neglect of large second order and time effects not really negligible. Experimental work has been in error through the assumption that deformation is proportional to the force producing it. From (4) and (5) it is evident that a more general form of statement of (I) and (II), including both is

III. PERCENTAGE DEFORMATION IS PROPORTIONAL TO PERCENTAGE CHANGE IN THE FORCE, OR

LOG DEFORMATION IS A LINEAR FUNCTION OF THE LOG OF THE FORCE PRODUCING IT.

However, time must be considered and must be the same for any two or more cases under comparison. Equation (6) is obtained by eliminating t from (4) and its time derivative. It indicates that the quantity $(an)^{-n}$ is a sort of generalized viscosity.

Since the general law of deformation must depend in some manner upon the strain and rupture of molecular bonds, the relaxation from a strained condition is of considerable theoretical interest. Relaxations amounting to half the original shear and continuing for ten minutes were observed in some pitches. The initial portion of the relaxation-time curve is almost identical with the initial part of the displacement-time curve preceding it. The relaxation function is of the same form as the deformation function (4), F being interpreted as the force just previously active. Our data on four widely different pitches indicate that for relaxation the constant m is the same, but a and n different, usually much less than for the preceding deformation. Thus for hard stearine pitch,

$$s=0.28\,t^{0.56}F^{2.0}$$

$$R=0.24\,t^{0.33}F^{2.0}$$

In relaxation, as in deformation, the time exponent is independent of the force that has been acting and the force exponent is independent of the time.

Another property of strained materials of great theoretical significance is the automatic release of internal strain with time if simply held in a fixed strained position. This property is associated with and complementary to the relaxation in form mentioned in the last paragraph. Deformed crystals tend to reform in an unstrained condition. Permanently deformed springs weaken gradually with time. We have seen springs of ferrous alloy receive a large permanent set on annealing at only 150° C. when in a strained condition. Amorphous bodies such as pitch, when deformed may be regarded as anisotropic but gradually return to an isotropic condition after a gradual molecular rearrangement requiring some minutes. In solids that rearrangement is much slower, in liquids much more rapid and in gases practically instantaneous. Since rate of deformation $ds/dt = ns/t$ is proportional to deformation s, a rupture theory is indicated in which the (molecular) rupture is self healing at a uniform rate.

The agreement of (4) with data by other observers obtained by other methods is of interest. Data by Green (A. S. T. M., 1919) relate to paints forced through capillary tubes by various static pressures of wide range. Taking his values for rate of discharge as a function of pressure for paints composed of linseed oil mixed with varying proportions of zinc oxide, the constant m in (4) was found to be 3.5 and the same not only for all pressures but for paints ranging from moderately thin mixtures to a thick paste. Data for computing n were not given, although a time effect attributed to inertia was noted. Data taken on an insulating oil with a MacMichael viscosimeter in this laboratory gave a value of $m = 0.77$, again without systematic variation. In this case F is the torque produced by a rotating cup of fluid on a disk suspended in it, and ds/dt is the angular velocity of the cup. Viscosity computed in the ordinary way varied by a factor greater than 2 as the velocity was varied from 1 to 30 R. P. M. This and other forms of absolute viscosimeter have been discredited because they indicated a variation of viscosity with velocity. It appears that the assumption, not the instrument, is in error. Time effects in the strain of elastic solids have been noted by many observers, but no precise data can be found for testing the formula.

The current through some leaky dielectrics attains a steady value only after several seconds or even many minutes from the time a steady E. M. F. is applied. This retardation is difficult to account for on the basis of any accepted theory of conduction; induction effects are not involved, and both displacement and Ohm's Law currents reach a steady value in a minute fraction of a second. Polarization, caused by an accumulation of ions, can be effective only near the electrodes while the effect of secondary ionization by collision is to increase rather than to decrease the current with time.

The mathematical theory of such conduction is similar in form to that applicable to deformable bodies, but the relation of this mechanical law to the electrical case under consideration is not merely a formal one. The electrical displacement consists of motions of electric charges impelled by potential gradients and if these charges are carried by material particles, the motions of the charges will be governed by the motions of the particles with which they are associated, the impelling force being electrical instead of mechanical. Corresponding with mechanical strain or displacement s in the above formulas, is q the electrical displacement; current density $i = dq/dt$, corresponds to ds/dt while potential gradient X corresponds to stress F in the mechanical equations. The tentative forms for electrical displacements are therefore

$$q = at^n X^m$$
$$i = ant^{n-1} X^m$$
$$di/dX = anmt^{n-1} X^{m-1}$$

Ohm's Law is a special form for which both m and $n = 1$ corresponding to pure viscosity in fluid motion. The special case of $m = 1$ and $n = 0$ is that of purely elastic displacements in ideal dielectrics.

The value of the new form lies in its flexibility and generality. Note that both q and i are *additive* ($q = q_1 + q_2 +$), being in general sums of terms of the same form but with different constants. Consider the case of leakage through mica. The current even after 30 minutes (7.10^{-13}) was still twice as great as after an hour and $^1/_3$ the value after 5 minutes. An elastic displacement current ($i = dq/dt$) would have come to zero in a fraction of a second. Adding a conduction current $(E-P)/R$ such that

$$i = \frac{dq}{dt} + \frac{E-P}{R}$$

does not represent the facts any better since the current does not drop suddenly to a steady value but decreases very gradually for a long time. The new formula represents this decay curve for mica very well if n is small and negative but not zero ($n = -0.2$).

Mr. J. E. Shrader has studied the variation of current with voltage and with time. The only material for which both are reported is xylene. For this liquid the equations

$$q = 3.7 \times 10^{-12} t^{0.33} X^{1.16}$$
$$i = 1.23 \times 10^{-12} t^{-0.67} X^{1.16}$$

have been deduced. For illustration, other rough values may be mentioned: varnished cambric $m = 0.70$, fuller board $m = 0.73$, cement paper $m = 0.54$. For castor oil $n = 1.0$, high flash oil $n = 0.23$, bakelite test cup $n = 0.74$, white India mica $n = -0.2$.

Both theory and experimental data indicate that the best technical dielectrics are those for which $n = 0$ or the smallest possible with m nearly unity and a very small over the range of operating temperatures. The watt loss per cycle of course depends directly upon n since it is a time integral over a cycle and approaches zero as n approaches zero. The possibility of establishing technical criteria of quality appears worth following up.

PITTSBURGH,
March, 1921.

The Common Occurrence of Aurora in the South of England. LORD RAYLEIGH. (*Nature,* March 31, 1921.)—There is a certain green line of wave-length 5578 Angstrom units, which is found in the light of the aurora. Several observers have noted that this line is of common occurrence in the light of the sky at night. Two years ago Slipher identified it at the Lowell Observatory, Cal., on every clear night on which he sought for it. Lord Rayleigh has renewed his quest for this line in England and has found it on many nights. It is, however, not always obtainable. One "fairly clear" night it was absent, while it appeared on many cloudy nights. He attributes his success to the use of Marion's "iso-record" plates especially sensitive in the green region of the spectrum. The experimenter proposes a program of "systematic comparison of the auroral intensity with sun-spots and magnetic disturbances, and also a comparison of its different intensities in Great Britain and elsewhere."

G. F. S.

The output of solid mineral fuel in France for November, 1920, was 2374 thousands of tons as against a monthly average in the year before the war of 3404. From January to December of last year the number of mine workers rose from 188,000 to 224,000. The deficiency of coal was supplied in order of decreasing importance by Great Britain, Germany, the Sarre Basin, the United States, and Belgium. (*La Nature,* April 2, 1921.)

G. F. S.

Paper as Substitute for Glass. (*Photographic Jour. of America,* February, 1921, p. 82.)—Paper negatives are not new. The older photographers remember them well, but like coffee, dry-plates, tin-types, and many other expedients in photography, they have been relegated to the limbo of forgotten things. Lately, however, owing to the very high cost of glass in Germany, two prominent German firms have placed on sale a special form of paper negative. The *Photographische Rundschau* describes the product, and the issue carries two advertisements of it. The Farbenfabriken Friedr. Bayer & Co. advertise under the trade name of " Plattenfort ", a negative paper, orthochromatic and highly sensitive, suitable for landscape and instantaneous work. Metallic frames, enameled with black, are provided as supports for the negative and fit in the ordinary dark slide. Exposure and development are made as with glass negatives. Owing to the opacity of the paper, the degree of development is not so easily judged as with glass, but it is claimed that this difficulty is soon overcome by experience. Development usually takes about five minutes. After fixing, washing and drying, the film is removed from the paper. The attachment of the film to the paper is made in such a way that simply pulling up one corner enables the whole extent to be drawn off, the operation being materially aided by the fact that the film, which is of gelatin, is fairly firm, and if fixed in an alum bath, is further hardened. The film can be used then as a negative. One advantage over glass negatives is that in pigment printing, such as carbon work, the film can be reversed, thus avoiding the duplicate treatment that is usual.

The other factory furnishes a plate of somewhat similar character, but the separation of the gelatin from the paper support is accomplished by cutting a bevel along the edges, so that the film extends a little beyond the paper base, when it can be easily removed. The advertisement of the first-mentioned firm claims the new form as " light, unbreakable, free from halation and capable of being copied from either side," in addition to being orthochromatic and very sensitive.

Selenium a Rare Element. (*U. S. Geological Survey Press Bulletin, No. 469,* April, 1921.)—Selenium is a rare and little-used element described by the Survey as having its greatest use in giving a red color to glass, such as that used on railroads for signal lights, and in coloring enameled ware red. It is also used to overcome the natural green color of ordinary glass. Selenium is peculiar in being a very poor conductor of electricity in the dark and a fairly good conductor in the light and is used in several electrical devices whose utility depends on this peculiarity. It has been used in telephoning along a ray of light and in transmitting sounds and photographs from one place to another over a wire.

GROUND-PLANE INFLUENCE ON AIRPLANE WINGS.*

BY

A. F. ZAHM, Ph.D., and R. M. BEAR, B.S.

Bureau of Construction and Repair, U. S. N.

Preface.—As the air action on the wings of an airplane may change materially, for a given speed and poise, when the craft leaves or approaches the earth's surface, the nature of this change has been deemed worth investigating with a model in the wind tunnel. A test made on a single British R.A.F. 6 aerofoil at 40 miles an hour in the 4′ x 4′ tunnel, at the Washington Navy Yard, is described in this article. The model was made of brass and measured 3 x 18 inches; it had the form of profile shown in Fig. 5.

Method of Measurement.—Fig. 1 shows the apparatus for the test assembled in the 4′ x 4′ tunnel. The aerofoil is held as usual at the extremity of the tapering spindle of the cross-arm wind balance, and has at one side a "ground-plane" parallel to the walls of the tunnel and held at its top and bottom edges in two grooved planks as shown. The plane, made of ⅜″ laminated pine, is about two feet wide along stream and chamfered to a thin edge on the side remote from the aerofoil. The guide boards are grooved for a distance of two feet, then chamfered up stream to edges flush with the floor and the ceiling. The grooves are ¼″ wide and spaced ½″ between centres; and each indicates the distance from the nearest face of the plane to the chord of the aerofoil at zero pitch.

For each setting of the ground-plane, the lift, drag, and pitching moment was measured in the usual way at 40 miles an hour and 0°, 4°, 8°, 12° and 14° pitch. In successive settings the ground-plane was moved laterally, by increasing steps, up to 16½″ then removed from the tunnel or set over against its wall; this farthest displacement being about the equivalent of removing the plane entirely, when allowance was made for the change of cross-section of the tunnel due to such removal.

Values of Lift and Drag.—The measurements of lift and drag are not tabulated but are plotted to ample scale in Figs. 2, 3, 4.

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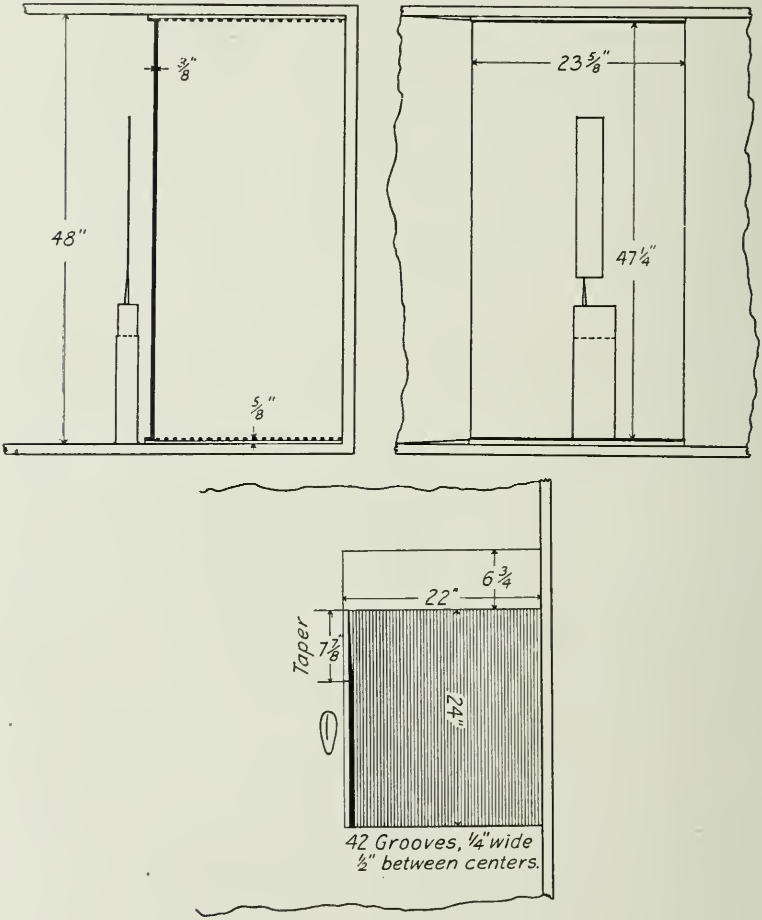
* Communicated by Dr. Zahm.

For all angles of incidence, as should be expected, the graphs of lift, drag, and lift-drag curve less and less rapidly as the ground-plane shifts from about half a chord length successively to greater distances from the aerofoil. They each tend to approach asymptotically a horizontal line which marks, for the represented quantity, the value obtained with the ground-plane indefinitely distant.

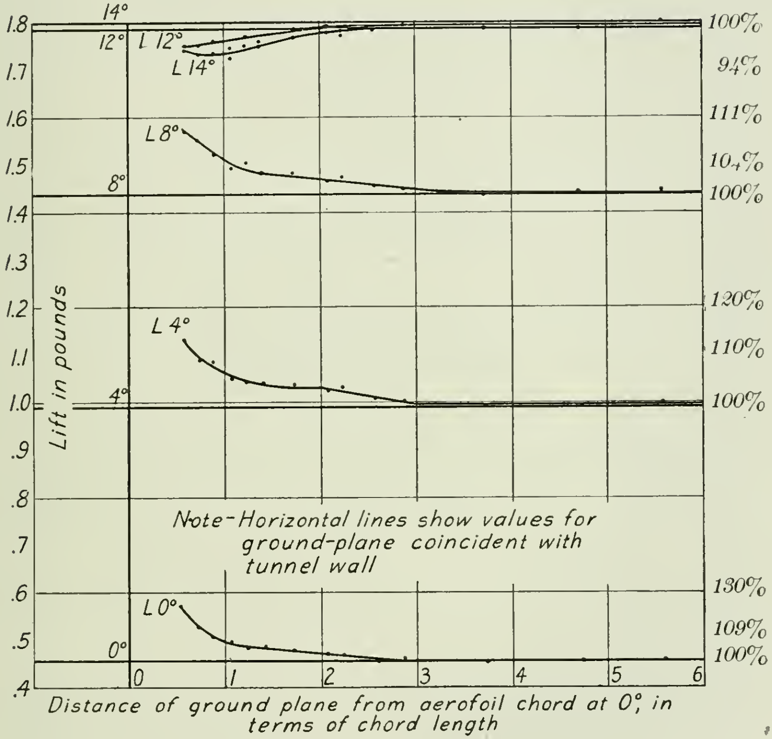
Fig. 1.



Aerofoil and ground-plane in 4 x 4 foot tunnel.

The curves are roughly exponential and may be expressed in the form $y = a + b\ e^{-cx}$, where a is the asymptotic value, $a + b$ the initial value, x the ground-plane distance, c the coefficient of decay of the ground-plane influence. The dotted lines in Fig. 4 are true exponential curves and coincide with the actual plotted data to within the degree of precision of the measurements. The numerical equations were derived from straight-line graphs of the data plotted on semi-logarithmic paper.

FIG. 2.

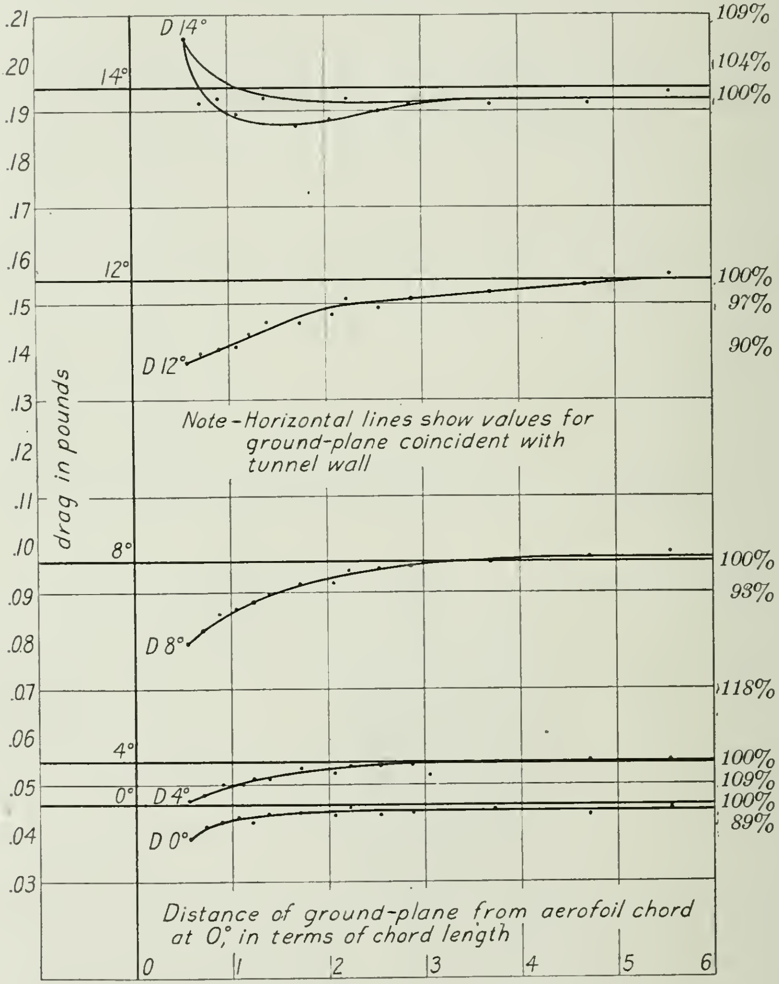


Lift *versus* ground-plane distance "*below*" aerofoil. Air speed 40.3 m. p. h.

As the pitch increases from its smallest value 0°, up to near the burble incidence, the lift falls, and the drag rises with enlarging gap between the aerofoil and the ground-plane; also for these conditions the curves are farther separated from their asymptotes initially, and reach practical contact with them farther from the origin. The asymptotes in all cases were hurriedly found from a single measurement, and in some instances seem to be less trustworthy than the curves approaching them.

As the pitch approaches the burble angle the ground-plane

Fig. 3.

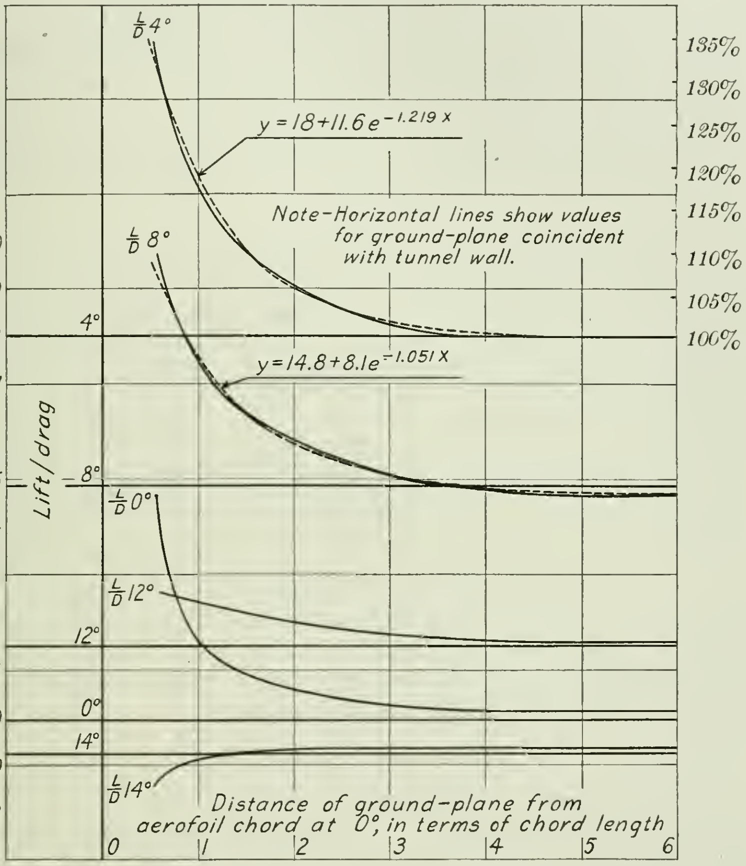


Drag *versus* ground-plane distance "*below*" aerofoil. Air speed 40.3 m. p. h.

effect diminishes roughly to 0, then becomes increasingly negative as far as the test discloses.

The numbers on the right-hand side of Fig. 4, at the top, indicate that the efficiency of a monoplane wing closely skimming the earth's surface may be increased 20 or 30 per cent. at 4° incidence. A still higher efficiency is indicated by the lift-drag curves for smaller angles of incidence.

FIG. 4.



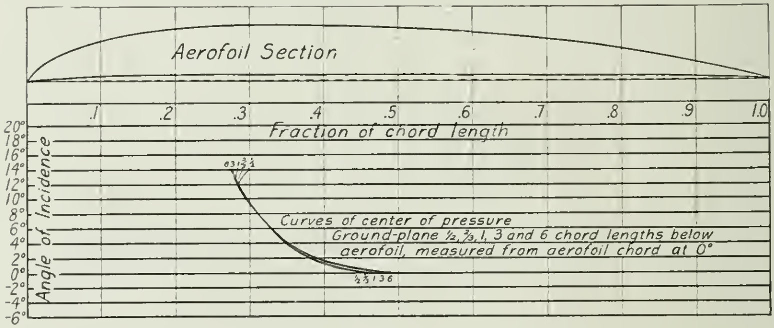
$\frac{\text{Lift}}{\text{Drag}}$ *versus* ground-plane distance "*below*" aerofoil. Air speed 40.3 m. p. h.

From Figs. 2 and 4 it appears that at small incidences a monoplane is considerably better sustained and more easily propelled near a ground-plane than when two or three chords above it. This fact might be turned to account in navigating above smooth water. It is distinctly marked by the pilot in trying to land at too high a speed on a flat surface. The airplane tends to rebound as if striking a denser medium.

A complete set of readings also were taken with the ground-plane "above" the aerofoil, that is opposite its more chambered surface. The most striking features of these readings are the great increase of lift with increasing incidences up to 12°, and the considerable increase of drag with proximity of the ground-plane at all the incidences used, *i.e.,* from 0° to 14°. The data were taken rather for completeness than for their practical importance, and hence are not given here.

Pitching Moment and Centre of Pressure.—From the measured lift, drag and pitching moment at 0°, 4°, 8°, 12° and 14° incidence, the centre of pressure was computed with the gap fixed first at one-half the wing chord, then successively at larger fixed distances. The travel of the centre of pressure is given in Fig. 5 and shows but slight ground-plane influence.

FIG. 5.



Aerofoil section and centre of pressure. Air speed 40.3 m. p. h.

CONCLUDING PARAGRAPHS.

Reference.—On completion of this article the writers' attention was called to an account, in the *Ace* for December, 1920, of a test by Mr. A. A. Merrill, of the ground influence on a biplane model at the single angle of incidence of 13°. He observed at this angle a slight ground effect and shift of the centre of pressure. He concludes: "This experiment then seems to show that the correction for ground effect upon landing is small though not negligible."

Dr. A. Betz reports,[1] for lift and drag only, the ground influence on a curved zinc plate to be quite similar to that found in the present test of a regular wing form. His model measured 10 x 60 millimetres, and was tested in a tunnel about two metres square in cross-section.

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[1] Zeitschrift für Flugtechnik und Motorluftschiffahrt, 1912.

Summary.—The present study discloses a very material ground-plane influence at small incidence and ground gap. The lift is augmented, the drag diminished; the lift-drag may be increased 30 to 40 per cent. Thus a sea gull or a suitably designed monoplane may skim the surface of smooth water with considerably greater economy than it can fly at a few wing depths aloft. But the pitching moment is only slightly affected by the presence of a ground plane.

The Magnetic Mechanical Analysis of Manganese Steel. SIR ROBERT HADFIELD and MESSRS. S. R. WILLIAMS and I. S. BOWEN, Oberlin College. (*Proc. Royal Society*, No. A. 692.)—This is a preliminary attack upon the problem of correlating the magnetic with the mechanical properties of ferromagnetic substances. Two sets of rods were used. They came from the same source but had received different heat treatment. All were heated to 1000° C. and then quenched in water. Half of them were subsequently annealed. Both types were subjected to an increasing magnetic field. The annealed specimen showed an increment of length with every increase of field-strength, while no change of length at all was observable in the case of the unannealed piece (Joule Effect). The effect upon intensity of magnetization produced by stretching rods of the two types was also investigated (Villari Effect). For the annealed rod and application of tension increased the intensity at all field strengths, but for the other rod tension made no difference. It was afterward found that the removal of a few thousandths of an inch of the outer layer of the unannealed rod caused it to cease to show any trace of being a magnetic substance.

"Whether we shall ever be able to interpret all of the mechanical properties of ferromagnetic substances from their magnetic behavior is a question, but from what has been accomplished there are fair promises, and no avenue seems more inviting than the one which has been followed in this study, where the magnetic and mechanical effects are so closely associated. Here is a splendid opportunity for co-operation between the large steel industries with their resources of materials, and the research laboratories with their resources of skilled investigators, to make a very thorough study of this field. X-ray methods, and the methods indicated above, seem to be about all the means we have at present to test the mechanical properties of a substance without injuring the sample tested. There are some advantages in the magnetic method."

G. F. S.

Method of Developing Highly Sensitive and Panchromatic Plates by Ordinary Light. (*Photographic Jour. of America,* February, 1921, p. 84.)—Dr. Lüppo-Cramer describes in the Swiss journal, *Die Photographie,* the following method by which plates that are usually developed in special safe-light may be developed without danger of fog in ordinary light. He found, in the course of studies on sensitizing plates, that the safranin dyes possess the property of diminishing sensibility of silver bromide in a remarkable degree. If to one of the ordinary developers a very dilute solution of phenosafranin (1 to 2000) is added in the proportion of 10 c.c. of the color solution to 100 c.c. of the developer, and the plate allowed to remain for about a minute in the mixture, the development may be then continued in bright yellow light. The plate can be lifted out of the liquid in order to examine the condition of the image, inasmuch as the action of the color is not merely that of a protecting screen, but a deep chemical or physical change in the silver bromide. Lüppo-Cramer states that it is possible to conduct the development in such a way that a special darkroom illumination is not needed. The plate is immersed in total darkness in the color solution for about a minute, and then placed in the developer. Just before this transfer, a stearin candle, placed at a distance of six feet from the plate, is lighted. In this convenient illumination the development of even very sensitive panchromatic plates may be carried out without any danger of fog. Even the liability to chemical fog on the part of the plates sensitized with isocyanin is avoided by the method.

Electric Power Production. (*U. S. Geological Survey Press Bulletin, No. 469,* April, 1921.)—The total production of electric power by public-utility companies in 1919 was 39 billion kilowatt-hours, according to the Survey. Of this power 62 per cent: was produced by fuels—35 million tons of coal, 11 million barrels of oil, and 21.7 billion cubic feet of gas—the remainder by water power.

The Photo-Electric Theory of Vision. J. H. J. POOLE. (*Phil. Mag.,* March, 1921.)—In an address to the British Association in 1919 Sir Oliver Lodge made the suggestion that the sensation of vision might be due to effect of photo-electrons emitted by some substance of the eye under the stimulus of the incident light. It is known that metals emit negative electrons when illuminated under suitable conditions. A careful examination of the black pigment and of the visual purple of the eye was made, but no evidence was secured that they emit electrons. There is therefore no experimental evidence for this attractive and picturesque theory.

G.F.S.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NICKEL.[1]

[ABSTRACT.]

THE larger part of the world's production of nickel comes from the famous pyrrhotite-chalcopyrite ores of the Sudbury district in Canada. These ores are at present smelted and refined by three processes, the larger tonnage being smelted in Canada and refined both there and in the United States by the Oxford Process. A natural alloy, Monel Metal, is produced from the same ores by roasting and reducing the copper-nickel matter shipped to New Jersey from the Canadian Smelters.

FORM AND USES.

Nickel is produced in the United States in several commercial forms. The greater tonnage is produced in the form of 50- or 25-lb. *ingots,* or *pigs,* which are used in the manufacture of nickel-bearing alloy steels. *Nickel shot* and *electrolytic nickel cathodes* are produced for the use of the manufacturers of non-ferrous nickel alloys, nickel-silver and cupro-nickel. Malleable nickel—sheet, strip, rod, wire—is produced for stampings, fittings, resistance and pyrometer wire, spark-plug points, and kitchen utensils. Nickel castings are produced for the chemical industries for use against corrosive solutions. Nickel is generally useful by reason of its anti-corrosive properties.

Monel metal is produced in the usual commercial forms, *i.e.,* castings, rods, sheet, wire, and is principally valuable because of its resistance to corrosion, its high strength at higher temperatures, and its resistance to the erosive action of superheated steam (use in turbines and steam valves).

Data relating to chemical composition and physical properties of pure and commercial nickel and of Monel metal are also given in the complete paper.

ALLOYS OF NICKEL.

Besides the nickel, or nickel-chromium alloy steels containing from 1–3.5 per cent. nickel and largely used for automobile and ordnance construction, there is a large number of other nickel-bearing alloys having very interesting and commercially useful properties.

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* Communicated by the Director.

[1] Circular No. 100.

Nickel-silver, containing from 52–80 per cent. of copper, 10–35 per cent. of zinc, and 5–30 per cent. of nickel, is used in sheet form for the base metal for silverplated household ware and other stampings and fittings, in the wire form for resistance wire, and in the cast form for automobile hubs, etc.

Cupro-nickel, containing about 15 per cent. of nickel, balance copper, is used for the manufacture of small arms bullet jackets.

Constantan, containing about 45 per cent. nickel, balance copper, is used largely for resistance and pyrometer wire.

Ferro-nickel, or 25–35 per cent. nickel-steel is used as resistance wire and as *Invar* having a low coefficient of thermal expansion.

Nichrome, and similar alloys, containing from 60–80 per cent. of nickel, together with chromium and iron, is used for resistance wire and as a heat or temperature resisting alloy.

Manganese-nickel alloys, containing from 2–4 per cent. of manganese and the balance nickel, are used largely for the manufacture of gasoline engine ignition points, or spark plugs.

RECOMMENDED SPECIFICATION FOR FLAT INTERIOR LITHOPONE PAINT—WHITE AND LIGHT TINTS.[2]

[ABSTRACT.]

The specification was prepared and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization. Representatives of paint manufacturers were called upon for suggestions and these were carefully considered in preparing the final draft.

The topics covered include the pigment, the liquid, the paint, methods of sampling and laboratory examination, the analysis of the pigment, and the preparation of the reagents. The laboratory examination covers the caking in the container, the color, weight per gallon, brushing properties, fastness to light, the water content, volatile thinner, the pigment, and the non-volatile vehicle.

The analysis of the pigment includes the qualitative analysis of water-soluble material, barium sulphate and siliceous material, zinc oxide, and calculations.

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[2] Circular No. 111.

The specification is not intended to apply to paints for outside exposure, but requires that such paints shall dry to dead flat opaque coats, adhering well to wood, metal, and plaster, and stand washing with soap and water, and show no material change in color on exposure to light.

THERMAL EXPANSION OF COPPER AND ITS IMPORTANT INDUSTRIAL ALLOYS.[3]

By Peter Hidnert.

[ABSTRACT.]

DATA on the thermal expansion of 128 samples of copper and its important alloys of various compositions, heat treatments, mechanical treatments, etc., are presented. The specimens contained from 56 to 100 per cent. copper and were prepared in a number of ways—cast, cast and cold rolled, extruded, extruded and cold worked, hot rolled and cold worked. Most of the samples were examined from room temperature to about 300° C. (Several specimens were cooled to −50° C. and then heated to + 300° C.)

Practically all available information on the thermal expansion of copper and its alloys is briefly reviewed.

A description of the apparatus and of the preparation of the samples, etc., is given.

Definite mathematical relations were found to exist between the coefficients of expansion and the copper content of most of the alloys investigated (Series II, III, V, VI). In general, the coefficient of expansion increases with a decrease in the copper content. The addition of lead or tin has a decided effect on the coefficient; the former element generally decreases, and the latter increases the coefficient.

Cast and Cold-rolled Copper-zinc Alloys (*Series II and III*). —In the case of alloys containing 62 per cent. copper it was found that the coefficients did not materially differ in cast or cold-rolled specimens, and for alloys, containing 90 per cent. copper, a similar agreement existed. For alloys with a copper content from about 62 to 90 per cent. the cold-rolled alloys have greater coefficients than the castings, and for alloys containing more than 90 per cent.

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[3] Scientific Paper No. 410.

copper the reverse is true. The coefficients of the inside sections of the castings are generally slightly less than those of the outside sections. A relation exists between the density and thermal expansion of the cold-rolled copper-zinc alloys (Series II).

Cast and Cold-rolled Copper-tin Alloys (Series V and VI).—The coefficients of the cold-rolled tin alloys are less than those of the castings. Cold rolling and drawing, therefore, cause a diminution in the values of the coefficients.

Hot Rolled and Extruded Samples (Series I, IV, and VI).—Owing to the large number of varying elements in the hot-rolled and extruded samples, it was impossible to determine the exact effect of each constituent element. In general, however, the coefficients are greater than the extrapolated values obtained from the quadratic equations of the copper-zinc alloys (Series II and III), showing a tendency toward increasing values as impurities are added.

The differences between the various series of samples are discussed in the section "Comparison of Results" and presented graphically in Figs. 39 to 43.

METHOD FOR DIFFERENTIATING AND ESTIMATING UNBLEACHED SULPHITE AND SULPHATE PULPS IN PAPER.[4]

By R. E. Lofton and M. F. Merritt.

[ABSTRACT.]

THIS paper discusses briefly the two possible bases on which to develop methods of differentiating between unbleached sulphite and sulphate pulps, viz.: (1) the different chemical natures of the two pulps due to different cooking treatments, and (2) the different amounts of ligneous matter that may be retained by the two pulps.

The methods followed by other investigators who have studied this problem are given, together with a brief critical commentary on each method. The methods reviewed include: Those used by Paul Klemm, one of whose methods consists in staining with malachite green alone and subsequently examining the color reaction under the microscope, and the second of whose methods consists in staining the fibres with malachite green and then with rosaniline

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[4] Technologic Paper No. 189.

sulphate; those used by C. G. Schwalbe, which consist, in one case, in treating the fibres first with a 0.05 N aqueous solution of ferric chloride, then with a weak solution of potassium ferrocyanide, and, in the other case, in first treating the fibres with a solution of copper sulphate and following this by treating with a solution of benzo-purpurine 10B; and those used by R. W. Fannon in applying the rosaniline sulphate and sulphuric acid stain and observing the color reactions, in one case with the unaided eye, and in the other case under the microscope.

A discussion of the chemical nature of rosaniline sulphate and of basic fuchsine, one of the dyes used in the method proposed below, shows that these two dyes are essentially alike, but that the latter is to be preferred for this purpose because of its greater solubility.

A few of the more interesting experiments with stains used in developing the method described below are given.

The method recommended by the authors for differentiating between unbleached sulphite and sulphate fibres follows.

The stain used is made by compounding equal volumes—one or two cm.^{3} of each is usually sufficient—of A and B, made as follows:

A—Malachite green	2 grams
Distilled water	100 cm^3
B—Basic fuchsine	1 gram
Distilled water	100 cm^3

Each new solution made up should be carefully tried out and adjusted for pulp samples of known composition.

The fibrous material is thoroughly disintegrated by boiling a small portion for a few seconds in a ½ per cent. aqueous solution of caustic soda and then shaking in a test tube with water. A few of the fibres are then placed on an ordinary microscope slide and dried with hard filter paper. Two or three drops of the compound stain are then placed on the fibres and allowed to act for two minutes, during which time the fibres are being teased about on the slide by means of teasing needles. The excess stain is then blotted up and the fibres rinsed once or twice with a few drops of a solution of 1 cm.^{3} of ordinary concentrated hydrochloric acid (sp. gr. 1.19) in 1000 cm.^{3} distilled water. This rinsing process is accompanied by teasing the fibres about in the liquid, and should not be continued for more than 30 seconds, otherwise too much stain may be taken from the fibres. The acid solution is then removed with filter paper and a drop or two of clear water applied and a cover glass placed over the fibres, which are then ready for examination under the microscope. Unbleached sulphite fibres are colored purple or lavender, and sulphate fibres are colored blue to bluish green. If the sulphite or sulphate fibres do not show their proper colorings, a few drops of *A* or *B* must be added to correct the one-sided action of the stain. When the stain functions properly on known pulps it is then ready for use on unknown samples.

The paper also contains tables showing the possibilities of making quantitative determinations of the percentages of these fibres in various mixtures of the two pulps.

"BLACK NICKEL" PLATING SOLUTIONS.[5]

By George B. Hogaboom, T. F. Slattery and L. B. Ham.

[ABSTRACT.]

NUMEROUS formulas have been proposed for the production of "black nickel" deposits such as are used extensively for producing a dark or black finish upon brass or other metals. Two types of solutions have been used, namely, the alkaline cyanide solutions and the neutral sulphocyanate solutions. Experiments showed that the former were very difficult to prepare and maintain of uniform composition, and therefore they cannot be recommended. It was found that a sulphocyanate solution having the following composition proved satisfactory:

	oz./gal.	g/l
Nickel ammonium sulphate	8	60
Zinc sulphate	1	7½
Sodium sulphocyanate	2	15

It is desirable to keep in suspension an excess of zinc carbonate, which maintains the neutrality and the zinc content of the solution.

"Black nickel" plating may be applied successfully to brass, either directly or after copper plating, to copper, and to steel which has been first coated with copper, nickel, or zinc. Where protection against corrosion is desired, the "black nickel" should be preceded by zinc plating. The wearing properties of the "black nickel" surface are largely determined by the quality of the lacquer subsequently applied.

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[5] Technologic Paper No. 190.

WAVE-LENGTH MEASUREMENTS IN ARC SPECTRA PHOTOGRAPHED IN THE YELLOW, RED, AND INFRA-RED.[6]

By F. M. Walters, Jr.

[ABSTRACT.]

For several years the Bureau of Standards has been conducting grating measurements in red and infra-red arc spectra by the aid of specially sensitized photographic plates to improve the data in this region and to find some element which would furnish lines suitable for wave-length standards in this region. To the measurements on 25 elements already made, the following are here added:

Element.	Region.	Number of Lines Observed.
Silver	5500—8273	6
Aluminum	5500—8774	10
Gold	5500—7510	17
Bismuth	5500—9657	27
Cadmium	5500—10,395	13
Mercury	5500—8195	16
Lead	5500—8272	14
Antimony	5500—9132	74
Tin	5500—9146	49
Zinc	5500—7799	16

The wave-length measurements are in the international system and are given to 0.01 A.

The elements were brought to luminosity by inserting a sample in copper or graphite electrodes between which the arc was maintained. The grating used had 297 lines per mm. and a 640 cm. radius. The spectra were photographed in the first order on plates sensitized with pinacyanol or dicyanin. The comparison spectrum was iron in the first, second, or third order, and in the reductions the wave-lengths established by interference methods were used.

A comparison of the wave-lengths measured for the same element by different observers shows that impurity and spurious lines must be looked for very carefully, that it is necessary to describe exactly the source of light and specify the observing conditions, and that the accuracy possible in wave-length measurements from the direct photography of normal spectra exceeds that in measurements from phosphor photography and bolometer measurements.

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[6] Scientific Paper No. 411.

A STUDY OF TEST METHODS FOR THE PURPOSE OF DEVELOPING STANDARD SPECIFICATIONS FOR PAPER BAGS FOR CEMENT AND LIME.[7]

By P. L. Houston.

[ABSTRACT.]

THIS technologic paper is published in order to aid the paper-bag manufacturers to meet the requirements of the lime and cement manufacturers in obtaining a suitable paper bag in which to ship their product. It contains information relating to the methods of testing and the apparatus employed in determining the quality of paper bags for lime and cement. For this purpose representative samples of paper bags are obtained from a number of the leading bag manufacturers. These bags are given identification numbers and the following tests are performed. These tests are divided into two classes, namely, ordinary and special tests. The first class includes all tests that are ordinarily performed on paper, such as weight in pounds of the standard size ream 25 × 40—500, bursting strength in points, tensile strength in kilograms, stretch in centimetres, folding endurance in number of double folds, percentage of fibre composition, percentage of ash and percentage of rosin sizing. The second class includes certain tests that are specially appropriate for paper bags. There are three distinct tests in this class. The first is a laboratory test performed on a recording instrument and gives numerically the stresses and strains that the paper of these bags undergoes in service. This test is called a resiliency or endurance test. The second is a service test and determines the breaking strength of the paper when the bags are filled with 94 pounds of sand and dropped a distance of three feet. This test is called a drop test, and its purpose is to reproduce service conditions since a bag is often dropped while being handled. A comparison is made of the results of the drop test with the results of the above resiliency test and the same papers prove strongest in both cases. It is thus proven that the resiliency test is a very good test for showing what the paper of a bag will do in actual service, and since it is strictly a laboratory test, it is highly to be recommended. The third is also a service test and determines the strength of the adhesives used in the bags; the bags are filled with 94 pounds of sand and jolted one inch high on an ordinary foundry

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[7] Technologic Paper No. 187.

jolter. This test is called a jolter test and somewhat duplicates the treatment that a bag undergoes while being jolted and jarred in shipment from manufacturer to consumer. The results of all these tests are tabulated, and from these data the very best quality bags are chosen. In the conclusions, special consideration is given this choice of best bags in determining the characteristics of a good quality bag, which are: good bursting strength, high tensile strength in both directions, high endurance or resiliency, high folding endurance, a fibre composition of not less than 50 per cent. strong manila and jute with the remainder as chemical wood, ash not over 3 per cent. and rosin sizing at least 3.5 per cent. As a final conclusion from the results of the various tests on the chosen best quality bags, these characteristics are drawn up in the form of specifications.

SOME PROPERTIES OF WHITE METAL BEARING ALLOYS AT ELEVATED TEMPERATURES.[8]

By John R. Freeman and R. W. Woodward.

[ABSTRACT.]

The Bureau of Standards as part of a general investigation of the properties and methods of testing the white metal bearing alloys has developed apparatus for determining their properties at elevated temperatures. This paper describes apparatus for determining the yield point and ultimate strength of these alloys in compression of temperatures up to 150° C. A similar apparatus is also described for determining the Brinell hardness at these elevated temperatures.

The results of compression tests and Brinell hardness tests obtained with this at 25° C., 50° C., 75° C., and 100° C. are given for the five following alloys:

Alloy No.	1	2	3	4	5
	per cent.	per cent.	per cent.	per cent.	per cent.
Copper	4.56	3.51	5.65	2.90	....
Antimony	4.52	7.57	6.90	10.50	10.03
Tin	90.02	88.92	87.36	61.55	5.02
Lead	absent	absent	.09	25.05	84.95
Iron	<.05	<.05	<.05	<.05	<.05

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[8] Technologic Paper No. 188.

Alloys Nos. 1, 3, 4, and 5 are the four alloys being recommended by the S. A. E. as standard alloys.

The results of these tests show that the three tin-base alloys maintain their properties better at the elevated temperatures than either the lead base or the intermediate alloy.

The effect of the addition of up to 5 per cent. of lead on the properties of the tin-base alloys was studied and found not to influence the yield point at 25° C. or 75° C.

The yield point of the tin-base alloys is not affected by heating for six weeks at about 100° C., but the yield point is lowered in the lead-base alloy by heating for two weeks at about 100° C.

SPECTROPHOTOELECTRICAL SENSITIVITY OF PROUSTITE.[9]

By W. W. Coblentz.

[ABSTRACT.]

THE present investigation is a continuation of previous work on the spectrophotoelectrical sensitivity of various substances.

At 20° C. the spectrophotoelectrical sensitivity curve of proustite has a slight maximum at about 0.61μ and a marked sensitivity with a wide maximum (at about 0.3μ) in the ultra-violet.

At $-170°$ C. the intrinsic spectrophotoelectrical sensitivity is greatly increased; but the maximum reaction is confined mainly in a sharp maximum at 0.578μ. No photoelectrical sensitivity was observed for radiation stimuli of wave-lengths extending from 0.7μ to 2μ.

Energy Losses in Commercial Hammers. E. MORRISON and R. L. PETRY. (*Physical Review*, March, 1921.)—When one body strikes another the total momentum is unchanged by the impact. The total kinetic energy is, however, less after the collision. Experiments with mechanics' hammers from a hardware store showed that those of the first grade lost 2.3 per cent., those of the second grade 5.3 per cent., and the third grade implements 9.3 per cent. Similar hammers obtained in a five-and-ten-cent store were found to lose 20 per cent. of kinetic energy. Railroad track hammers lost from 2.3 to 5.5 per cent.

G. F. S.

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[9] Scientific Paper No. 412.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE POSSIBLE PATHOGENICITY OF *BACILLUS BOTULINUS*.[1]

By Ruth B. Edmondson, L. T. Giltner, and Charles Thom.

[ABSTRACT.]

CALCIUM CHLORIDE injected into guinea-pigs with toxin-freed bacilli or spores of *B. botulinus* acts as an accessory factor in producing botulism. Under such conditions the behavior of *B. botulinus* is similar to that reported by Bullock and Cramer for the organisms of gas gangrene and tetanus.

On the basis of experiments tried, toxin-freed spores of the Boise strain of *B. botulinus,* when fed in sufficiently large doses to guinea-pigs, can produce the specific disease and death, while the Nevin strain similarly fed does so occasionally. A limited pathogenicity is thus indicated.

Foods suspected of containing *B. botulinus* should be destroyed, not heated and eaten.

THE DETECTION OF METHYL ANTHRANILATE IN FRUIT JUICES.[2]

By Frederick B. Power.

[ABSTRACT.]

ALTHOUGH methods for the detection or quantitative determination of methyl anthranilate in essential oils have long been in use, the isolation of the substance from such products as fruit juices in a form sufficiently pure to permit of its identification was found to involve somewhat unexpected difficulties, which, however, were ultimately overcome.

It was found that the preliminary isolation of methyl anthranilate in the requisite degree of purity could not be effected by direct extraction with ether. It is, therefore, best to first distil the fruit juice in a current of steam. The methyl anthranilate is

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* Communicated by the Chief of the Bureau.

[1] Published in *Arch. Internal Med.*, 26 (1920), 357–366.

[2] Published in *J. Am. Chem. Soc.*, 43 (1921), 377–381.

then extracted from the distillate by chloroform and the solvent removed. The residue, when dissolved in dilute sulphuric acid and diazotized, is finally tested with β-naphthol or with dimethylaniline, preference being given to the former reagent on account of the greater delicacy of the reaction.

Having developed a practical and trustworthy method for the detection of methyl anthranilate in grape juice, commercial samples of this product as well as those of known purity will be examined for the presence of the respective compound. These results will be published later.

In his biography of John William Strutt, Lord Rayleigh (*Proc. Royal Soc.*, A. 695), Sir Arthur Schuster makes the following comparison of three great Victorian physicists—"Kelvin felt strongly and expressed himself forcibly. To him the mechanism of the ether and of the ultimate constituents of matter could not be otherwise than the mechanism of the gross matter he could handle in the laboratory. That was the Alpha and Omega of his convictions. Stokes was more cautious; where Kelvin was angry, he only smiled mysteriously. In purely scientific matters, and in private conversation or unreported speeches, one suspected that Stokes had something of the iconoclast in his composition, and he enjoyed being told of any experiment that could not be reconciled to current theories. Rayleigh was purely judicial, repressing his personal predilections. To put it into colloquial language, where Kelvin would say: 'This is all nonsense,' and Stokes answer: 'Perhaps, but all the same it is a hard nut for you to crack,' Rayleigh would ask, 'What is the evidence?' He did not hide his dislike of some of the modern theories, but he went far enough to admit that, if it be impossible to demonstrate experimentally the relative motion of a body and the ether, our belief in the existence of the ether must be reconsidered."

Atomic Weight of Antimony.—H. H. Willard and R. K. McAlpine of the University of Michigan (*Journ. Am. Chem. Soc.*, 1921, xliii, 797–818) have made a redetermination of the atomic weight of antimony by the analysis of antimony bromide. The atomic weight was found to be 121.773.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

A WIDE ANGLE ASTRONOMICAL DOUBLET.[1]

By F. E. Ross.

THE present lens is an outcome of the war-time activity of the Eastman Kodak Company in lens design and manufacture. A lens of 6 inches aperture and 48 inches focal length has been designed and constructed by the company for the aerial service, which passed the most rigid tests. The present lens is nearly identical with this, the difference being in the glass used, a lower index flint being substituted which enabled a complete simultaneous elimination of field curvature and astigmatism to be obtained over a total field of 25°. Correction of this kind has heretofore not been secured in any type of lens, for a total field angle greater than 10°. Thus the field of critical definition has been more than doubled in the present lens compared with the best of previous types which makes it useful for many astronomical purposes. One of these lenses has already been constructed by the Brashear Company for the Yale Observatory. The result of the test has not yet been received.

THE ORIENTATION OF THE GRAINS IN A DRIED PHOTOGRAPHIC EMULSION.[2]

By L. Silberstein.

THE problem treated in this paper consists in finding the amount of orientation and of the average efficient area of the silver halide grains (small plates) in the final dry state of a photographic emulsion spread over a film base, the distribution of the directions of the plate-normals in the initial state being haphazard. The efficient area and the final distribution law of directions are given in terms of the contraction ratio of the layer, *i.e.*, of the ratio of its final to its initial thickness.

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* Communicated by the Director.

[1] Communication No. 107, published in *J. Opt. Soc. Amer.*, March, 1921.

[2] Communication No. 112, published in *J. Opt. Soc. Amer.*, March, 1921, p. 171.

Removal of Deposited Copper from a Silver Cathode.—Copper may be determined quantitatively in the electrolytic way by its deposition on a silver cathode. HOWARD WATERS DOUGHTY and BENJAMIN FREEMAN, of Amherst College (*Journ. Am. Chem. Soc.*, 1921, xliii, 700–704), have devised a novel procedure for the rapid and complete removal of the deposited copper after the analytic determination has been completed. The cathode is immersed in an ammoniacal solution of an organic compound containing a trichloromethyl or a tribromomethyl group. One solution contains ten per cent. of trichloroacetic acid dissolved in aqueous ammonia which is prepared by mixing one volume of aqua ammonia of specific gravity 0.90 and one volume of water. Another solution is obtained by dissolving either chloroform or carbon tetrachloride in a mixture of equal parts by volume of concentrated aqueous ammonia and alcohol. Approximately ten minutes are required for complete removal of the copper. Apparently three atoms of copper react with two molecules of trichloroacetic acid. This procedure may also be used for the removal of deposited cadmium and zinc from the silver cathode.

J. S. H.

Separation of Certain of the Rare Earths from Each Other.—ARTHUR C. NEISH and J. W. BURNS (*Canadian Chem. and Metal.*, 1921, v. 69–74) have devised the following procedure for the separation of thorium, cerium, neodymium, praesodymium, and lanthanum. The solution, containing these metals as nitrates, is treated with either hydrogen sulphide or sulphur dioxide to convert the cerium into the cerous condition. The solution is then boiled until any excess of the reducing agent has been expelled, and is treated in an atmosphere of carbon dioxide, with a slight excess of one of the following compounds: lead carbonate, zinc carbonate, cupric carbonate, zinc oxide, or red lead (Pb_3O_4). Thorium is thus precipitated as its hydroxide, and is removed by filtration. Sufficient potassium permanganate is added to the filtrate to oxidize the cerium to the ceric condition; the solution is heated to boiling; a slight excess of either lead carbonate, manganous carbonate, zinc carbonate, or red lead is added while stirring; and the precipitated ceric hydroxide is immediately collected by filtration. The filtrate thus obtained is treated with a slight excess of either silver oxide, magnesium oxide, or magnesium carbonate at a temperature of 60° C.; neodymium and praesodymium are precipitated, and may be separated from each other by a lengthy series of fractional precipitations with ammonia. Lanthanum is present in the filtrate from the neodymium and praesodymium, and is obtained by precipitation with sodium hydroxide.

J. S. H.

NOTES FROM THE U. S. BUREAU OF MINES.*

ESTIMATION OF PLATINUM IN ORES.

By C. W. Davis.

THE high price of platinum has stimulated prospecting for new occurrences of this metal, and the Bureau of Mines has received many inquiries concerning the commercial assay of ores for platinum. Methods in use have varied widely, and frequently results submitted by assayers and chemists have been misleading or worthless, through inexperience or use of an improper method. Technical Paper 231, recently published by the bureau, entitled "The Detection and Estimation of Platinum in Ores," summarizes the various methods for the detection of the metal and gives a selected method for the commercial estimation of platinum in ores. A short supplementary paper on "The Estimation of Small Quantities of Gold, Silver, and Platinum in Material High in Copper" has been issued in mimeographed form.

RETORT FOR ASSAYING OIL SHALES.

By L. C. Karrick.

THE BUREAU OF MINES has received many inquiries on the subject of assaying oil shales, both from individuals who desire to make their own assays while in the field and also from commercial assayers and research men. Many retorts now in use for experimental work on oil shales are suitable when used in the capacity for which they were developed. However, for convenience and accuracy in rapid assays in the field and laboratory, and for providing a basis of comparison between assays, there is need for a retort and method whose specifications are definitely fixed, and which will give results agreeing closely in duplicate determinations. The retort used by the Bureau of Mines, in the research work on oil shales now in progress at Salt Lake City, Utah, and at Boulder, Colo., was developed in the bureau's laboratories and has been found to be convenient in use and capable of yielding reproducible results.

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* Communicated by the Director.

Several devices were tried by the bureau before the one now in use was adopted. It was suggested from the field retort used by Winchester and described by him in Bulletin 641 of the United States Geological Survey. Changes were made in the size of retort, the angle of take-off of the delivery tube, the style of heater, and general assembly of parts; and there were added a reflux condenser, jacket, and cover. All the parts can be easily obtained from any dealer in chemical supplies, and readily assembled by anyone. It is more fully described in a paper entitled "A Convenient and Reliable Retort for Assaying Oil Shales," recently issued by the bureau in mimeograph form.

SLATE DUST IN ASPHALT ROAD SURFACE MIXTURES.

By Oliver Bowles.

From 80 to 95 per cent. of the gross production of all slate quarries is discarded as waste. The Bureau of Mines has undertaken a study of the industry for the purpose of devising means of reducing the proportion of waste, and of utilizing the unavoidable waste. The latter has received special attention.

As intimations had been received from several sources that slate flour constituted a superior filler for road asphalt mixtures, an attempt was made to obtain more definite data as to its adaptability for such a use. The coöperation of manufacturers was requested, and as a result several companies offered to test the material in their experimental laboratories. Samples of finely pulverized slate were submitted for this purpose. Tests were made both on asphalt bonded briquets and on standard sheet asphalt pavement mixtures.

The results indicate that for resistance to impact slate flour is about equal to other fillers in bonded briquets, and somewhat superior in sheet surface mixtures. In cementing value it is superior to both limestone and Portland cement in asphalt bonded briquets, and intermediate between them in standard sheet surface mixture. Elutriation tests indicate that slate flour contains approximately 15 to 25 per cent. more of the fine dust that constitutes effective filler than either limestone, trap rock, or Portland cement. In volume weight slate is about equivalent to limestone, and approximately 10 per cent. superior to Portland cement. The cost of slate flour is little more than half that of Portland cement, but its ability to compete in price with limestone is not yet established.

The tests were not sufficiently comprehensive to give conclusive results, but they are definite enough to suggest possibilities of such importance as to induce further and more extended research both by slate producers and by manufacturers of asphalt road mixtures. It is highly desirable that the conclusions reached be verified by practical tests on experimental roads.

Development After Fixation. (*P. J. A.*)—The following is important in this connection, as it refers to a discovery made about twenty years ago by Professor F. E. Nipher, of Washington University, St. Louis, Mo. In 1901, he published in the Transactions of the St. Louis Academy of Sciences the results of experiments on very long overexposure. Giving, for instance, plates that required only a fraction of a second, several hours' exposure, necessarily to a fixed object, he found that not only was the picture reversed, a fact already known, in a general way, but the development could be made in full light; in fact, must be so made for if developed in darkness the plate will fog. Nipher's experiments were repeated a few months later by members of the Photographic Section of The Franklin Institute, Philadelphia, and the results were exactly as had been described. A rapid plate, which had been given four and one-half hours' exposure, was passed around a lighted room for the examination of those present, and then developed in front of a sixteen-candlepower electric light, while another plate similarly exposed, but which had been developed in the dark-room, was fogged. The plate developed in the light, on being fixed, came out as a perfectly clear positive.

Anticipation of Daguerre. (*Photographic Jl. of Am.*, April, 1921, p. 157.)—It is asserted that in a publication, entitled "*Pfennig-Magazin*," in the year 1840, an account is given of a process of copying copper-plate engravings, drawings and writings by contact with a prepared paper. It is claimed that five days before Arago presented to the French Academy the account of Daguerre's process, a certain Mr. Breyer deposited with the Brussels Academy a sealed package containing a statement of his first results, and requested that it should be opened at the meeting of the Academy on the 5th of October of that year. Dr. Limmer, President of the Photographic Institute of the Technologic High School at Darmstadt, is authority for the statements. Claims of this character are often made without sufficient warrant. The publication mentioned is not likely to be found in the United States; nor, indeed, outside of the country of publication. Almost all great discoveries are foreshadowed, and generally by workers who have remained comparatively obscure. Glauber (1604–1668) was aware of the fact that organic substances stained with silver nitrate will turn black when exposed to light.

Photo-Stereo-Synthesis. (*La Nature,* April 2, 1921.)—Once more the name of Louis Lumière is associated with a new and interesting optical device, in this case a method of producing the appearance of solidity without resorting to the means hitherto employed to invoke the stereoscopic effect. When one looks at a man's face not all parts are seen at the same time with equal clearness. The focus of the eyes of the observer can be changed in ranging over the face so that now the nose, now the ears are in focus. One of the marks of solidity is the necessity of the eye's varying its focus in roving over the object.

M. Lumière takes six photographs of the face. In the first the end of the nose and the moustache are sharp, while the rest of the face is hazy. In the second the plane of sharp definition has moved back to the eyes and the forehead. The features in front of this plane as well as those back of it are not clear. Thus the plane of sharp outline moves by steps from the nose to the ear. From these six negatives as many positives are made, but the latter are of small density, so that the superposition of the six transparent images gives a composite image equal in intensity to one ordinary positive image. These six positives are supported with a slight interval between them and with their planes parallel. Upon looking at the positives in a direction perpendicular to their plane and from a suitable distance a striking impression of relief is caused.

Two arrangements are described from such negatives as have been discussed. In the first the lens of the camera is translated about a line parallel to its axis, after the sharp image of the previously mentioned nose has been focussed on the plate in such manner that any line of the lens continues parallel to itself. At the same time a similar motion is imparted to the plate. When certain geometrical relations are observed the image of the nose will keep its position on the plate unchanged, while the image of the lobe of the ear, for example, will move over an area of the sensitive plate and thus will cause a blurred image. The effect of this arrangement is to reduce the depth of field of the lens. The image of the nose will be sharp, but the images of other parts of the face at different distances from the lens will be hazy. For another setting the nose will be blurred while the ear will be sharply defined. The second method depends upon the use of a pair of inverting prisms.

The ingenuity of the principle employed and its incorporation in appropriate apparatus are alike worthy of the reputation of the eminent French technician.

G. F. S.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 20, 1921.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 20, 1921.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership, since last report, 7.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

Mr. Coleman Sellers, Jr., gave an account of the life and work of Isaiah Lukens, a noted mechanician of the early part of the nineteenth century, a charter member of the Institute, its first Vice-President and first Chairman of its Committee on Inventions. He then introduced Mr. Henry R. Towne, Chairman of the Board, The Yale and Towne Manufacturing Company, New York City, who described and exhibited an odometer made by Mr. Lukens and originally purchased from the Lukens Estate by Mr. John H. Towne, father of the speaker. He then presented the apparatus to the Institute for its collections. The Chairman expressed his appreciation of the gift on behalf of the Management and the Institute.*

The paper of the evening entitled, "The Motorship: Its Economic Position with Reference to the Oil Fired Turbine Steamer," was then presented by Dr. Charles E. Lucke, Professor of Mechanical Engineering, Columbia University, New York City. He stated that the future of the American merchant marine will be determined by the success of its cargo-carrying ships measured by transportation costs in competition with foreign vessels. The motorship has been highly developed and extensively built in Europe, but not in America. The geared steam turbine steamer has been and now is the main reliance in this country and is in competition at sea with the European motorship. Each has at present a proper but different economic position which will be determined by analysis of weights, fuel consumptions and costs. He said the machinery of both classes of vessel is still undergoing changes and the relative competitive position of these two types of vessel in the future will be determined largely by these changes and a second analysis will estimate the effects of the changes. The opinion was expressed that there will probably be always a place for both types of ship, the problem being to define the position in which each is best, by analysis of characteristics, and to estimate the comparative numbers of each required for handling world trade. The subject was illustrated by lantern slides.

After a discussion participated in by Mr. Henderson and others, including Mr. J. N. Mahoney, of New York City, who described some new improvements in the internal combustion engine recently made by Mr. Elmer E. Sperry, a unanimous vote of thanks was extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

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*The remarks of Mr. Sellers and Mr. Towne will appear in a later number of the JOURNAL

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 6, 1921.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, April 6, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following reports were presented for final action:

No. 2749: Surface Combustion Burner. The Edward Longstreth Medal of Merit awarded to William Barton Edison, of New York.

No. 2752: Philbrin Ignition System. Dismissed without prejudice.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 24, 1921, at 8 o'clock, with Mr. Charles E. Bonine in the Chair.

Mr. W. E. Ruder of the Research Laboratory, General Electric Company, Schenectady, New York presented the paper of the evening entitled, "The Science of Electric Welding." A brief historical review of the subject was given and the methods and apparatus used at present in practice were described. The nature of the metal deposit was also discussed and the recent work done along the line of perfecting it. The commercial aspect of electric welding was considered from the point of view of the manufacturer and the electricity supply company. The subject was illustrated by lantern slides.

A discussion followed the reading of the paper, in which Doctors Northrup and Hering, Mr. Eglin and others took part. The thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, March 31, 1921, at 8 o'clock, in the Hall of the Institute. The meeting was called to order by Mr. Coleman Sellers, Jr. Dr. Gordan F. Hull of the Technical Staff, Office of the Chief of Ordnance, War Department, Washington, D. C., presented the paper of the evening entitled "Some Applications of Physics to Ordnance Problems."

Experiments to determine the law of air resistance were described as well as the results obtained by holding a projectile in an air stream and measuring the force upon it. Photographs were shown of the disturbed air about a projectile and the underlying physical principles involved. New apparatus and new methods for determining the retardation of a projectile were described and an account was given of experiments to determine the stability of a shell. The subject of pressures in guns and the resulting expansion as well as causes contributing to the bursting of guns were also given consideration. The subject was illustrated by lantern slides.

After a discussion the thanks of the meeting were conveyed to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, April 13, 1921.*)

RESIDENT.

MR. LEONARD T. BEALE, 705 Lafayette Building, Philadelphia, Pennsylvania.
MR. J. E. BREWER, West Conshohocken, Pennsylvania.
MR. RODRICH BOEHMKE, 827 Spring Garden Street, Philadelphia, Pennsylvania
MR. EARL R. MILLER, Electric Storage Battery Company, Philadelphia, Pennsylvania.
MR. EDWARD W. PARKER, 437 Chestnut Street, Philadelphia, Pennsylvania
DR. HAAKON STYRI, S. K. F. Research Laboratory, Front and Erie Avenue, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. A. R. SANDT, 716–718 Metropolitan Life Building, Minneapolis, Minnesota.

CHANGES OF ADDRESS.

MR. W. E. FLETCHER, Atlas Powder Company, Wilmington, Delaware.
MR. RICHARD P. HARVEY, R.F.D. No. 1—Box 16, San Mateo, California.
MR. H. M. KAUFMANN, Mutual Chemical Company of America, 110 William Street, New York City, New York.
MR. GUSTAV LINDENTHAL, 7 Dey Street, New York City, New York.
MR. FRED J. MILLER, Stockton, New Jersey.
MR. WILLIAM S. MURRAY, 709 Sixth Avenue, New York City, New York.
MR. G. F. OTT, 325 Hansberry Street, Philadelphia, Pennsylvania.
MR. W. L. PLACK, S. W. Corner Twelfth and Locust Streets, Philadelphia, Pennsylvania.
MR. G. BERKELEY REED, 182 Broad Street, New London, Connecticut.
MR. CHARLES E. RICHARDSON, Charles E. Richardson & Co., 18 E. 60th Street, New York City, New York.
MR. W. F. RITTMAN, Salem, Ohio.
MR. JOSEPH B. ROHRMAN, 15 Aronimink Place, Drexel Hill, Pennsylvania
MAJOR R. A. WIDDICOMBE, 26 North Jefferson Street, Chicago, Illinois.

NECROLOGY.

Mr. Howard S. Graham, 435 Chestnut Street, Philadelphia, Pennsylvania.
Mr. Jacob Hasslacher, 70 Westland Avenue, Boston, Massachusetts.
Mr. J. S. Whitney, 1509 Arch Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Annual of Photography for 1921.

American Electrochemical Society Transactions. Vol. 36, 1920.

Chambers, T. W.—Gyroscopic Compass. 1920.

Chemical Engineering Catalog. 1920.

Chemists Year Book. 1920.

Daw, A. and Z. W.—Compressed Air Power. No date.

Eddington, A. S.—Space Time and Gravitation. 1920.

Foerster, E.—Johows Hilfsbuch für den Schiffbau. 1920.

Heriot, T. H. P.—Manufacture of Sugar from Cane and Beet. 1920.

Holmes, A.—Nomenclature of Petrology. 1920.

Ivens, E. M.—Pumping by Compressed Air. 1920.

Jellinck, K.—Lehrbuch der Physikalischen Chemie. 1914.

Kershaw, B. C.—Use of Low Grade and Waste Fuels for Power Generation. 1920.

Monckton, T. A.—Hydrogen Manual. 1919.

Photograms of the Year. 1920.

Rideal, E. K.—Ozone. 1920.

Rideal, S.—Carbohydrates and Alcohol. 1920.

GIFTS.

Ottonis de Guericke Experimenta Nova (ut Vocantur) Magdeburgica de vacuo spatió Primùm à R. P. Gaspare Schotto, è Societate Jesu, & Herbipolitanæ Academiæ Matheseos Professore: nunc verò ab ipso Auctore Perfectiùs edita, variisque aliis Experimentis aucta . . . 249 pages, illustrations, folio. Amstelodami, 1672.

(From Mr. William Forsyth.)

Acheson Graphite Company, Electric Furnaces. Niagara Falls, New York, 1920. (From the Company.)

Aldrich Pump Company, Hydraulic Machinery. Allentown, Pennsylvania, 1920. (From the Company.)

Allis-Chalmers, Bulletin No. 1087C. Milwaukee, Wisconsin, 1920. (From Allis-Chalmers.)

American Foundry Equipment Company, American Sand Blast Equipment. New York City, New York, 1920. (From the Company.)

American Galco Incorporated, Catalogue. New York City, New York, 1920. (From the Corporation.)

Armstrong Cork and Insulation Company, Nonpareil Insulating Brick. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Atlantic Refining Company, The Story of Motor Oils. Philadelphia, 1920. (From the Company.)

Atmosphere Conditioning Corporation, Bulletin Nos. 120 and 450. Philadelphia, Pennsylvania, 1920. (From the Corporation.)

Automatic Fuel Saving Company, Automatic Combustion Control. Philadelphia, Pennsylvania, 1920. (From the Company.)

Blanchard Machine Company, The Blanchard Grinder. Cambridge, Massachusetts, 1920. (From the Company.)

Bristol Company, Bristol's Recording Instruments. Waterbury, Connecticut, 1920. (From the Company.)

Brown, A. and F., Company, Power Transmission Machinery. New York City, New York, 1920. (From the Company.)

Brown Hoisting Machinery Company, Catalogue K-1921. Cleveland, Ohio, 1920. (From the Company.)

Burton-Rogers Company, Catalogue of Hoyt Electrical Instruments. Boston, Massachusetts, 1920. (From the Company.)

Canadian Engineering Standards Association, Standard Specification for Steel Railway Bridges. Ottawa, Canada, 1920. (From the Association.)

Canadian Mining Institute, Transactions, Vols. xvi to xxii. Ottawa, 1913–1919. (From Mr. Wm. J. Haines.)

Carnegie Institution, Year Book No. 19. Washington, District of Columbia, 1920. (From the Institution.)

Cleveland Twist Drill Company, Handbook for Drillers. New York City, New York, 1920. (From the Company.)

Copper Clad Steel Company, "Copperweld Wire." New York City, New York, 1920. (From the Company.)

Cowan Truck Company, Transveyor Picture Book. Holyoke, Massachusetts, 1920. (From the Company.)

Crouse-Hinds Company, Bulletin No. 304-A. Syracuse, New York, 1920. (From the Company.)

Cushman Chuck Company, Catalogue, 1921. Hartford, Connecticut, 1920. (From the Company.)

Cutler-Hammer Manufacturing Company, C-H Motor Control Apparatus for Pumps, Compressors and Similar Service. Milwaukee, Wisconsin, 1920. (From the Company.)

Davis-Bournonville Company, Bulletin on the Oxygraph. Jersey City, New Jersey, 1920. (From the Company.)

De Laval Steam Turbine Company, Centrifugal Pumps. Trenton, New Jersey, 1920. (From the Company.)

Denver Rock Drill Manufacturing Company, Waugh "90" Drills. Denver, Colorado, 1920. (From the Company.)

Donnelly Systems Company, Steam Circulation. New York City, New York, 1920. (From the Company.)

Duff Manufacturing Company, Catalogue No. 104. Pittsburgh, Pennsylvania, 1920. (From the Company.)

Erie Foundry Company, Erie Steam Hammers. Erie, Pennsylvania, 1920. (From the Company.)

Fastfeed Drill and Tool Corporation, Catalogue No. 14. Toledo, Ohio, 1920. (From the Corporation.)

Flory, S., Manufacturing Company, Catalogue on Flory Hoists. Bangor, Pennsylvania, 1920. (From the Company.)

Fort Wayne Engineering Company, Bulletin Nos. 5009 and 5010. Philadelphia, Pennsylvania, 1920. (From the Company.)

Foundry Equipment Company, Coleman Ovens for Cores and Molds. Cleveland, Ohio, 1920. (From the Company.)

Great Britain Meteorological Office, Report of Proceedings of Paris Conference, 1919. London, England, 1921. (From the Director.)

Hanna Engineering Works, Catalogue No. 10. Chicago, Illinois, 1920. (From the Works.)

Hagan Corporation, The Hagan System Boiler Regulation. Pittsburgh, Pennsylvania, 1920. (From the Corporation.)

Haiss, Geo., Manufacturing Company, Incorporated, Booklet No. 1020. New York City, New York, 1920. (From the Company.)

Harris Brothers Company, Structural Steel. Chicago, Illinois, 1920. (From the Company.)

Harvard College Observatory, Circular Nos. 222–223. Cambridge, Massachusetts, 1920. (From the Observatory.)

Holz and Company, Incorporated, Bulletin No. 41. New York City, New York, 1920. (From the Company.)

Illinois Stoker Company, Catalogue "L." Alton, Illinois, 1920. (From the Company.)

Ingersoll-Rand Company, Compressed Air for the Road Builder. New York City, New York, 1920. (From the Company.)

Iowa Board of Railroad Commissioners, Report for 1919. Des Moines, Iowa, 1920. (From the Board.)

Jones and Lamson Machine Company, The Hartness Automatic Die for Cutting Screw Threads. Springfield, Vermont, 1920. (From the Company.)

Kellogg, M. W., Company, Perforated Radial Brick Chimneys. New York City, New York, 1920. (From the Company.)

Larner-Johnson Valve and Engineering Company, The Johnson Hydraulic Valve and Differential Surge Tank. Philadelphia, Pennsylvania, 1920. (From the Company.)

Lidgerwood Manufacturing Company, Bulletin No. 2. Philadelphia, Pennsylvania, 1920. (From the Company.)

Link-Belt Company, Book No. 416. Chicago, Illinois, 1921. (From the Company.)

Lynn Commissioner of Water Supply, Annual Report for Year 1919. Lynn, Massachusetts, 1920. (From the Commissioner.)

MacArthur Concrete Pile and Foundation Company, The Pedestal Pile. New York City, New York, 1920. (From the Company.)

McVicker Engineering Company, Graphic Production Control. Minneapolis, Minnesota, 1920. (From the Company.)

Merrill Company, Twenty-four-page Booklet. San Francisco, California, 1920. (From the Company.)

Michigan Board of Agriculture, Fifty-eighth Annual Report for 1919. Fort Wayne, Indiana. (From the Board of Agriculture.)

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National Tube Company, National Bulletin No. 14C. Pittsburgh, Pennsylvania, 1921. (From the Company.)

National Twist Drill and Tool Company, Catalogue No. 11. Detroit, Michigan, 1920. (From the Company.)

New Hampshire Public Service Commission, Reports and Orders from June, 1920, to August, 1920. Concord, New Hampshire, 1920. (From the Commission.)

Ohio Blower Company, Power Plant Foundry and Factory Equipment. Cleveland, Ohio, 1920. (From the Company.)

Ohio Body and Blower Company, Core Baking and Japanning. Cleveland, Ohio, 1920. (From the Company.)

Ottawa River Storage Commission, Report for 1915–1920. Ottawa, Canada, 1920. (From the Director.)

Pawling and Harnischfeger Company, Bulletin 5X. Milwaukee, Wisconsin, 1920. (From the Company.)

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Ready Tool Company, Red-E Tools, Bridgeport, Connecticut, 1920. (From the Company.)

Roberts and Schaefer Company, Booklet. Chicago, Illinois, 1920. (From the Company.)

Rockwell W. S. Company, Bulletin No. 222. New York City, New York, 1920. (From the Company.)

Ross Heater and Manufacturing Company, Incorporated, Catalogue F. Philadelphia, Pennsylvania, 1920. (From the Company.)

Royal Academy of Sciences, Proceedings of the Section of Sciences, Vol. 20. Amsterdam, Holland, 1920. (From the Academy.)

Royal Astronomical Society of Canada, The Observer's Handbook for 1921. Toronto, Canada, 1921. (From the Society.)

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Sellers, William, and Company, Incorporated, Sellers Injectors. Philadelphia, Pennsylvania, 1920. (From the Company.)

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Starrett, The L. S. Company, Catalogue No. 22. Athol, Massachusetts, 1920. (From the Company.)

St. Louis Frog and Switch Company, General Catalogue No. 2. St. Louis, Missouri, 1920. (From the Company.)

Sturtevant, B. F., Company, Catalogue 242, July, 1917. Boston, Massachusetts, 1920. (From the Company.)

Superior Sand and Gravel Company, Builders' Blue Book for November, 1920; December, 1920, and January, 1921. Detroit, Michigan, 1920. (From the Company.)

Superior Service Products Company, Catalogue No. 2. Chicago, Illinois, 1920. (From the Company.)

Thomas, J. G., Detrick Arches with Coxe and Type E Stokers. Philadelphia, Pennsylvania, 1920. (From Mr. J. G. Thomas.)

U. S. Light and Heat Corporation, Electric Arc Welding. Niagara Falls, New York, 1920. (From the Corporation.)

Union Switch and Signal Company, Drop Forgings. Swissvale, Pennsylvania, 1920. (From the Company.)

Union Tool Company, Union Tool Small Catalogue. Orange, Massachusetts, 1920. (From the Company.)

United States Chief of Engineers, Annual Report for the Year 1920, Part 1–2. Washington, D. C., 1920. (From the Chief of Engineers.)

Wright Manufacturing Company, Catalogue No. 10. Lisbon, Ohio, 1920. (From the Company.)

Worcester Polytechnic Institute, Fifty-first Annual Catalogue for 1920–1921. Worcester, Massachusetts, 1920. (From the Institute.)

Worthington Pump and Machinery Corporation, Booklet BK-3000. New York City, New York, 1920. (From the Corporation.)

Yingling, C., and Son, The Yingling Double Action Eccentric Motion Shaking Grate. Newark, New Jersey, 1918. (From C. Yingling and Son.)

BOOK NOTICES.

JOURNAL OF INDIAN INDUSTRIES AND LABOUR. Vol. 1, Part 1. Published by order of the Government of India. Calcutta, February, 1921.

This is a new venture, in the form of a very substantial and well printed issue, octavo size, containing 111 pages and 7 full plates, the latter illustrating an extended article on the Calcutta Research Tannery. The text, as will be expected, relates almost entirely to industrial questions in India. Some of these are suggestive of our own troubles, such as "Trade Disputes in Bengal." The only article directly relating to chemistry is on "Clove oil from clove stems." From this we learn that Africa is the home of clove production, the supply coming principally from Zanzibar and Pemba. In these two islands about 52,000 acres are under cultivation. The output amounts to many millions of pounds, and for the season of 1918–19 the total yield is said to have been nearly 29,000,000 pounds. Many of the trees are nearly a century old. The article, which is by S. T. Gadre, industrial chemist to the Government, United Provinces, Cawnpore, states that the oil distilled from the clove stems contains 95 per cent. of eugenol, so that it is a valuable addition to our supply of that compound.

It seems not to be stated at what intervals the parts will be issued, but the volume will consist of four parts and is priced at Rs 4–8–0, a statement which might have been translated in some equivalent in the money of western Europe.

HENRY LEFFMANN.

THE HEALTH OF THE INDUSTRIAL WORKER. By Edgar L. Collis, M.A., M.D., and Major Greenwood, M.R., C.P. Containing a chapter on Reclamation of the Disabled, by Arthur J. Collis, M.A., M.D. With an introduction by Sir George Newman, M.D. 8vo. xvi–438 pages and index. Philadelphia, P. Blakiston's Son and Co. Price $7.00 net.

The diseases that are more or less directly due to occupation have been attracting much attention of late years. Times have changed since those in which the state and the employer considered it none of their affair to take care of the health, moral or physical, of workingmen and workingwomen.

Much of the progress in this field has probably been due to the natural evolution of social conditions, but not a little of it has been the result of struggle against selfishness, struggle organized and carried out by devoted men and women who earned much obloquy by their efforts. In many fields of work much still remains to be done, and there is no denying the fact that workers of both sexes are still largely to blame for the accidents and diseases that affect them, for they often neglect the safety rules that are advised and disregard the safety appliances that are provided.

The book begins with a highly interesting history of industrial conditions in early England. The conclusion is drawn that until the beginning of the 18th century, industry, apart from agriculture, had no appreciable effect upon the health of the nation. It is generally agreed that the invention of the steam engine developed the factory system, and made a profound change in England, and later, in other parts of the world. It is true that, centuries before, occasional instances of collection of numerous workers in one industry and under one employer are noted, but they are rare. It is stated, for example, that in the time of Henry VII, a clothier, known as "Jack of Newbury," employed over 1000 persons, but this is merely an isolated instance. The only factories in early England were the parish water or wind-mills at which grain was ground.

Reference is made to the commonly received view that the first half of the eighteenth century was the golden age of English industry, in which its material advantages were happily combined with health-giving attributes. Macaulay, indeed, opposed such view, and, in one of his essays, ridiculed Robert Southey's glorification of contrast between "rose bushes and poor rates" as against "steam engines and independence." Macaulay considered the latter a preferable condition. He, however, spoke in 1846, in Parliament, strongly in favor of reform in the condition of factory workers. Unfortunately, the data for judging of the mortality and morbidity in these earlier periods are scanty, but what information is at hand shows that the average duration of human life has increased. How far this increase is due to smaller families, and to lowered infant mortality, cannot be definitely answered. The authors consider proved the fact that the data at hand show that the sanitary conditions of the hand-laboring population changed for the worse in the industrial revolution and remained for fifty years a disgrace to civilization.

The course of state control through the centuries is traced in an interesting manner, from the Ordinance of Laborers (1349) remedying conditions brought about by the great plague, followed by other laws to secure better enforcement of the original one. The Statute of Apprentices was passed in Elizabeth's reign. A striking feature of this act was the regulation of the hours of labor, not by limitation as at the present time, but by imposition. In summer the work began at 5 A.M. and continued until after 7 P.M. The trained workman was forbidden to change his trade or to leave the district in which he was employed. Later, came the Poor Laws, so dark a blot upon England's legislation the iniquities of which are so well known to readers of Dickens' novels.

It would be interesting to go in this manner over the whole work for it is crowded with data of the most striking and valuable nature, but space does not permit such extensive consideration. One fact may be mentioned, that is interesting in these days, when so many men have been maimed in war. Mock (quoted from his work on Industrial Medicine and Surgery) states that one concern found advantage in employing men who had lost a leg or an arm, giving several reasons which are set forth for this result. Mock is also quoted to the effect that if the casualty list of industry could be printed every day in the papers, the people of the country (U. S.) would be appalled at the figures. In one year alone it is said the casualties are over four times as large as the entire casualties of the American troops on the battle fields of Europe. It must, however, be borne in mind that the number of persons employed in industries far exceeds the number in the A. E. F. at its greatest size.

As an example of the care and thoroughness with which the work has been compiled, the chapter on the bearing of the use of alcohol upon the health and efficiency of workers is well worth reading. Some of the more frequently heard claims, *pro* and *con*, are shown to be unworthy of consideration. The opinion expressed is that alcohol is not necessary to the human being in health, and that its use diminishes efficiency in some industries.

The work is based on extensive consultation of authorities and large personal experience. Excellently printed on good paper, it constitutes a most useful addition to the literature of a subject which is second to none in importance at the present time.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 99, Accelerations in Flight, by F. H. Norton and E T. Allen. 8 pages, illustrations, quarto. Washington, Government Printing Office, 1921. This report deals with the accelerations obtained in flight on various airplanes at Langley Field. The instrument used in these tests was a recording accelerometer of a new type designed by the technical staff of the National Advisory Committee for Aeronautics. The instrument consists of a flat steel spring supported rigidly at one end so that the free end may be deflected by its own weight from its neutral position by any acceleration acting at right angles to the plane of the spring. This deflection is measured by a very light tilting mirror caused to rotate by the deflection of the spring, which reflected the beam of light onto a moving film. The motion of the spring is damped by a thin aluminum vane, which rotates with the spring between the poles of an electric magnet. Records were taken on landings and take-offs, in loops, spins, spirals, and rolls. It was found that the loading in a fairly heavy landing reached a maximum of 5 g., in a loop it reached a maximum of about 3.7 g., in a spin a maximum of about 3 g., while in a roll it attained the value of 4.2 g., showing that this maneuver puts a greater strain on the machine than any other. A JN–4H was pulled as suddenly as possible out of a dive at 50, 60, 70 and 80 miles an hour. The records show that the time elapsed between pulling the stick back and reaching the maximum acceleration was independent of the air speed and amounted to about 0.9 seconds. These accelerations are slightly lower than the theoretical accelerations that would be obtained if the machine were suddenly turned to the angle of maximum lift. It was also found that an airplane had a certain definite period of vibration which could be excited by the engine, but which was not at all dependent upon it, as the vibrations were nearly as evident when the machine was gliding with a dead stick. This period of vibration appeared to be inversely proportional to the weight of the machine. It is concluded from these tests that in no reasonable stunting would the load in flying ever exceed a factor of four and one-half times the normal stress.

Report No. 101, The Calculated Performance of Airplanes Equipped with Supercharging Engines, by E. C. Kemble, Harvard University. 52 pages, diagrams, quarto. Washington, Government Printing Office, 1921.

In part 1 of this report are presented the theoretical performance curves of an airplane motor equipped with a supercharging compressor. Means for estimating the temperature rise in the compressor are outlined. Since the compressor will be designed for a definite normal pressure ratio, the gross power output under normal conditions is easily computed when the intake temperature is known. In the case of a gear-driven compressor, the net power is obtained by subtracting the power absorbed by the compressor from the gross power. For use in determining the size and power absorption of the compressor needed in a given case, a formula for the variation of the volumetric efficiency of the motor with intake temperature and exhaust pressure is derived.

A graphical method is outlined whereby performance curves for either type of motor-compressor unit at all speeds and altitudes may be laid out with the aid of assumed compressor characteristics. Comparative performance curves for a Liberty motor operating with a turbine-driven compressor, a gear-driven compressor, and without supercharging, are derived in an illustrative calculation.

Part 2 of this report presents an estimation of the performance curves of an airplane fitted with a supercharging motor. If the heat leak from gas turbine and exhaust pipes to the water jackets is prevented, and the cooling system is kept under constant pressures, no additional radiator equipment should be required when a supercharging compressor is fitted to an airplane engine.

In an illustrative example horizontal flight speed and maximum climbing speed curves are worked out for the Lepere two-seater fighter when equipped with supercharging and non-supercharging engines, and with both fixed and variable pitch propellers.

A supercharging installation suitable for commercial use is described, and it is shown that with the aid of the compressor a great saving in fuel and a considerable increase in carrying capacity can be effected simultaneously.

In an appendix the writer derives a theoretical formula for the correction of the thrust coefficient of an airscrew to offset the added resistance of the airplane due to the slip-stream effect.

Report No. 105, Angles of Attack and Air Speeds During Maneuvers, by E. P. Warner and F. H. Norton. 12 pages, illustrations, quarto. Washington, Government Printing Office, 1921. In seeking further information as to the nature of maneuvers and as to the maneuverability characteristics of airplanes, continuous measurements of the angles of attack and air speeds at several points along the wings have been made during spins and loops. Very striking results have been obtained with reference to the rolling velocity and the distribution of load in spins and the variation of the angle of attack in loops, a surprisingly large range of angle being experienced during slow loops.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 185, Pennsylvania Mining Statutes, Annotated by J. W. Thompson. 1221 pages, 8 vo, price $1.00. Bulletin 195, Underground Conditions in Oil Fields, by A. W. Ambrose. 238 pages, illustrations, plates, diagrams, maps, 8vo, price 65 cents. Bulletin 198, Regulation of Explosives in the United States, with Especial Reference to the Administration of the Explosives Act of October 6, 1917, by the Bureau of Mines, by Charles E. Munroe. 45 pages, 8vo, price 10 cents. Bulletin 205, Flotation Tests of Idaho Ores, by Clarence A. Wright, James C. Parmelee and James T. Norton. 70 pages, plates, 8vo, price 25 cents. Plan for Conducting Work Under Operating Regulations to Govern the Production of Oil and Gas Under the Act of February 25, 1920. 20 pages, diagrams, 8vo, price 5 cents. Technical Paper 269, Analysis of Iowa Coals, by George S. Rice, A. C. Fieldner and F. D. Osgood. 28 pages, 8vo, price 5 cents. Washington, Government Printing Office, 1920–1921.

Canada Department of Mines, Mines Branch: Preliminary Report on the Mineral Production of Canada During the Calendar Year 1920, prepared by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 24 pages, 8vo. Ottawa, King's Printer, 1921.

La physique des Rayons X, par MM. R. Ledoux-Lebard et A. Dauvilliers. 441 pages, illustrations, 8vo. Paris, Gauthier-Villars et Cie., 1921.

The New Philosophy of Modern Science, by W. W. Strong, B.S., Ph.D. 194 pages, 8vo. York, Pa., Kyle Printing Company, 1920. Price $4.50.

Oil Fuel: Its Supply, Composition, and Application, by Edward Butler. Fourth edition, revised and greatly enlarged. 310 pages, illustrations, 12mo. London, Charles Griffin & Company, Ltd.; Philadelphia, J. B. Lippincott Company, 1921.

The Clayworker's Hand-Book: A Manual for All Engaged in the Manufacture of Articles from Clay, by Alfred B. Searle. Third edition, revised, enlarged and largely rewritten. 381 pages, illustrations, 8vo. London, Charles Griffin & Company, Ltd.; Philadelphia, J. B. Lippincott Company, 1921.

Historical Review of the Object, Organization and Activities of the Chemical Alliance, Inc., During the World War, 1917-1918. 82 pages, 8vo. New York, The Chemical Alliance, 1920.

The Kiln Drying of Lumber, a practical and theoretical treatise, by Harry Donald Tiemann, M.E., M.F. 3rd edition, 318 pages, illustrations, plates, diagrams, 8vo. Philadelphia, J. B. Lippincott Company, 1920. Price $4.50.

Cam Design and Manufacture, by F. B. Jacobs. 121 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1921. Price $2.00.

Ammonia and the Nitrides, with Special Reference to Their Synthesis, by Edward B. Maxted, Ph.D., B.Sc. 116 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son and Company, 1921. Price $2.00.

The Distribution of Scientific Information in the United States, by Robert B. Sosman. 99 pages, 8vo. Reprinted from the *Journal of the Washington Academy of Sciences,* vol. ii, No. 4, February 19, 1921.

Mellon Institute of Industrial Research of the University of Pittsburgh. Eighth Annual Report on the Industrial Fellowships of the Mellon Institute, by Raymond F. Bacon, Director, for the Fiscal Year Ended February 28, 1921. 19 pages, illustrations, 8vo. Pittsburgh, Pa., 1921.

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THE APPLICATION OF RADIO TO NAVIGATION PROBLEMS.*

BY
REAR ADMIRAL W. H. G. BULLARD.
Director, Naval Communication Service, Navy Department, Washington, D. C.

Ladies and Gentlemen: The excuse, or reason if you please, for my appearing before you this evening in the rôle of a lecturer, I lay entirely to your Secretary, Major Owens, who, I presume, took as a clue a remark accredited to the late Mark Twain, who, in dropping in to see an acquaintance, remarked that "having ten minutes to spare, he wished to inflict it on someone who had not the ten minutes to spare." I wish to pay tribute to the indefatigableness of your Secretary, for it was his persuasiveness and accomplishments of speech which worked on an unwilling subject and completely disarmed him, securing the promise of my appearing before this distinguished audience.

I approach the subject matter with considerable misgiving, for neither my training nor my education has been such that would cause me, of my own volition, to appear before a body of scientific men and women in the disguise of a lecturer. I have repeatedly thought that a course of public speaking or talking, if you please, should be included in a course at our National Academy, our Naval Academy, but my ideas along these lines have met with no sympathetic response. I have thought I should take up a course in public speaking, but was finally deterred by a previous experience in trying to develop my memory. I purchased a set of seven books designed to improve the memory, and started in systematically to master the subject, and having gone laboriously and conscientiously through the first book, I laid them down and was never able afterwards to remember where I put them. So much for the success of reading the first volume, so I have given up all hope of improving my memory or the art of public speaking, and forgotten them both. I would rather you would think of what I have to say in the light of a talk, rather than a lecture, and I approach the various heads in which my talk divides itself as a user of apparatus rather than as a designer or engineer, as the service of which I have the honor to be the head is an administrative and operative service, not a designing or engineering one; therefore, what I have to tell you will be the practical side and not the scientific side. This may be disappointing to this scientific audience, but if so, you can lay your blame on him to whom I attribute my troubles, your Secretary, Major Owens.

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* Presented at a meeting of the Electrical Section held Thursday, November 4, 1920.

I was asked to speak on the subject of radiotelegraphy as applied to the science of navigation, and the application of this science to the operation of saving life or property at sea.

One of the first applications of radiotelegraphy as an aid to navigation, aside from the simple transmission of radio messages to and from ships relating to matters of distress, to which it is unnecessary to refer, and one of the simplest applications, was the sending out of the so-called time signals at stated intervals. Time is an important element in navigation, and one of the two coördinates which fixes the position of a ship at sea, namely, longitude, is determined entirely from the element of time. Difference of longitude is only a question of difference of time, and the actual longitude measured from a given meridian is the difference between the times measured from that meridian and the local time. The time carried by mariners is obtained from a delicate chronometer, which is regulated to Greenwich Mean Time, and which, if absolutely correct, registers the correct mean time, counting the meridian of Greenwich, England, as the zero point. Knowing this time and the local time, the determination of the longitude resolves itself into a question of arithmetic, and the difference of time, and hence the longitude, is at once known. Ship chronometers, however, are subject to errors and rates, and these errors and rates must be determined to apply to the clock face time in order to obtain the correct Greenwich Mean Time. The finding of the local time is a question of observing a heavenly body's altitude, and applying appropriate formulæ. Thus it is seen how important it is to know the correct Greenwich Mean Time, as the local time is easily obtained by observation.

Correct 75th meridian time is kept at the U. S. Naval Observatory, and it becomes the problem of carrying this time to ships at sea, so the errors of the mariners' chronometers on 75th meridian time and hence on Greenwich or zero mean time may be known. This error applied to the clock time gives the correct Greenwich Mean Time. This correct 75th meridian time is sent from the Naval Observatory by means of radio signals. Five minutes before each noon local 75th meridian time, a telegraph circuit is associated with the pendulum of the master clock at the Observatory, and a relay at the Arlington radio station. Once each second the electric circuit is momentarily closed by the circuit maker of the clock's pendulum and the relay at the radio station is energized. This closes a switch which permits a radio dot to be broadcasted into the ether. All ships having radio receiving sets tuned to receive Arlington's wave, receive this signal as a dot in the telephone receivers. Signals are started out five minutes preceding noon 75th meridian time, and a dot is sent once each second, with a break in the dots on the 29th second and the last five seconds of

Central control station, Navy radio, New York.

each of the first four minutes, and finally the last ten seconds of the last minute. The time of exact noon, or the instant of 75th local noon, is a little longer contact after the ten-second break. The mariner marks the time shown by his chronometer and hence knows at once his error. It is advisable to check the time this way every day, but if this is impossible it should be taken after a lapse of several days, and with the two errors and the elapsed time the rate is known, which, applied to the error in one day, will give the error for any succeeding day. Time signals are sent out broadcast by the following stations on the Atlantic, Pacific and Gulf coasts in the United States:

Washington.—Daily at 11:55 A.M. to noon and 9:55 to 10 P.M., standard time, 75th meridian.
Key West.—Same as Washington.
New Orleans.—Daily at 11:55 to noon, standard time, 75th meridian time.
Darien, C. Z.—Daily at 12:55 P.M. to 1 P.M., 75th meridian standard time.
North Head, Wash.—Daily, except Sundays and holidays, at 11:55 A.M. to noon, 120th standard meridian time.
Eureka, Cal.—Same as North Head.
Point Arguello, Cal.—Same as North Head.
San Diego, Cal.—Same as North Head.
San Francisco, Cal.—Daily at 11:55 A.M. to noon and 9:55 to 10 P.M., 120th meridian standard time.
Great Lakes, Ill.—Daily at 10:55 A.M. to 11 A.M., 90th meridian standard time.

Time signals sent out from Washington, Key West and New Orleans, are from the Naval Observatory at Washington; those from the Pacific coast stations from the Naval Observatory at Mare Island, Calif. Signals from Darien, in the Canal Zone, are sent out from a master clock there, which is regulated each day by the signals sent out from Key West, and is thus sent one hour later. This is for the benefit of shipping in the vicinity of the Canal Zone, that cannot receive Key West.

Some European administrations send out time signals in a manner similar to that described, but most of them use different systems of dots and dashes, with the result that mariners must have the different signals sent out from each particular station. An international system would be highly desirable, so that a ship of any nationality could receive the signals under one common system, but efforts to bring about this desirable procedure have not yet proved successful. The French use a system that would be highly desirable, as it is so designed that fractions of a second of time may be easily obtained, but this system does not well adapt itself to transmission by telegraph lines. The time signal system by radio, and certainly for land use, has probably been in existence in the United States longer than in any other country, and to change the system of receiving would disturb the thousands of customers who now use it. Its simplicity recommends it, and it is doubtful whether the more complicated, but scientific system, would be favored by the thousands of ships that now daily get their time.

Even the master clocks at the Observatories may have an error, and this is sent out from time to time; there is also an error introduced by the lag, due to the various relays the electrical circuit traverses. This is constant for a given station, and is published for the information of all. Thus the lag of the time signal sent from Key West is .07 of a second on the actual time, and which must be allowed for.

Connected with the general subject of time signals, but not related to the general question of navigation at sea, but of which I wish to speak for a moment, is the determination of the difference of longitude by means of radio signals. Interchange of radio signals between two stations furnishes a ready means of determining the difference of longitude between the two stations. This furnishes an added means of testing out a survey that has been made by triangulation from certain fixed points, and affords a ready means of quickly determining the difference of longitude between two points, by setting up temporary portable wireless sets. This method is particularly valuable in regions where triangulation is carried on with difficulty, and offers a means of obtaining differences of longitude over greater differences than can be served by instruments involving human sight.

Such a determination of the difference of longitude between observatories at Washington and Paris, was carried out by French and American observers in the fall and winter of 1913–1914. The radio signals were sent out both from the United States Arlington radio station, at Radio, Virginia, and the radio station at Eiffel Tower in Paris.

THE PROGRAM AND METHODS OF RADIO WORK.

At each station the program of radio work was essentially the same. At Radio, for example, the Leroy clock controlled the emission apparatus so as to send out three series of 420 signals, called rhythmic signals, omitting, for purposes of identification, the 60th, 120th, 180th, 240th, 300th, and 360th signals.

As the Leroy transmitting clock did not automatically omit any signals, it was necessary for one of the radio observers to effect these omissions by the manipulation of a switch in the circuit from this clock to the sending apparatus. The omitted seconds are referred to as interruptions.

The intervals between successive signals were approximately $0^{s}.99$ mean time, and each signal was about $0^{s}.5$ long, a long signal being considered better than a short one by the radio observers when working with faint signals. This made it necessary for the radio observer to concentrate his attention on the beginning of the signal. In order to increase the number of coincidences that could be observed in the limited time during which uninterrupted use of the ether could be secured, it was planned to compare the rhythmic signals with an intermediary mean-time chronometer beating half-seconds at each station instead of with the observatory standard clocks which emitted signals only once in two seconds. The chronometer was compared by the radio observer with the observatory clock before and after the radio work, which usually occupied a little over an hour. During this period dependence was placed on the rate of the chronometer. All these comparisons were made by the coincidence method by ear, by the use of telephone receivers. The principle underlying such comparisons is essentially the same as that of the vernier, in this case coincidence of divisions of time being established by ear and in the case of the vernier the coincidence of divisions of space being established by the eye. When comparing the rhythmic signals with the chronometer, coincidences took place about once in 50 seconds, and in the case of emission signals generally seven or eight were observed in a series. In comparing the chronometer with the observatory clock, coincidences took place about once in three minutes and in general four were observed in each comparison.

The work of the radio observer was to listen, for example, to the rhythmic and chronometer beats in his telephone receivers and to note by the chronometer face the time of a coincidence of beats, to record this, and then, picking up the count from the chronometer but counting on the rhythmic beats, to count up to the next omitted signal in the rhythmic series, called an interruption, to record this, then to observe the next coincidence, and so on to the end of the series. By means of an induction coil the chronometer signals were reduced in intensity, when necessary, until they were of about the same faintness as the radio signals. The observation of the interruptions was especially difficult in the case of the over-sea signals, since many of these signals were not heard. However, if one interruption in a series was observed, the rest could readily be supplied; and, even if none was observed, it was an easy matter to supply them all, assuming that the longitude was already approximately known.

By means of the records of the coincidences and of the interruptions, it was possible to determine from each observed coincidence the chronometer time of any signal in the series of rhythmic signals which might be selected as the reference signal. This was done for each coincidence and the mean was used. In order to eliminate from the mean the effect of error in the adopted rate of gain of the emitting clock on the comparing clock, due to errors of observation, the signal whose number in the series corresponds to the mean of the numbers of the signals at which coincidences were observed was taken as the reference signal. As this number is different for the two stations, the signal corresponding to the mean of the two numbers was used as the reference signal, thus rendering such errors negligible, though not completely eliminating them.

Having thus determined the chronometer time of a certain reference signal in a series, this was transposed into Riefler clock time by means of the comparisons between the chronometer and the clock and was then transposed into local sidereal time by the application of the clock correction. In cases where the rhythmic signals were observed at both stations we have, then, the local sidereal time of a given reference signal at each station, and the difference is the longitude except as affected by transmission time, the effect of which is to make the longitude determined by signals emanating from Washington too large and those determined by signals from Paris too small by the time occupied in transmission.

The errors of the clocks involved were checked each night by a continuous succession of star observations to determine the correct sidereal time.

Taking account of all errors of whatever kind, and the personal errors of the observers, and the fact that the personnel involved interchanged their duties between Washington and Paris, the final difference of longitude was determined to be:

$$5^h\ 17^m\ 36^s.653 \pm {}^s.0031.$$

THE WASHINGTON-GREENWICH LONGITUDE.

The Washington-Paris longitude given in the American Ephemeris and Nautical Almanac from 1901 to 1915, $5^h\ 17^m\ 36^s.75$, is correlated with the Paris-Greenwich longitude, $0^h\ 9^m\ 20^s.97$, which has been superseded by the value given above, corresponding to a Washington-Paris longitude of $5^h\ 17^m\ 36^s.71$. This depends on the adjustment of the Washington-Greenwich longitude made by Schott in 1897, which gave for that longitude $5^h\ 8^m\ 15^s.78 \pm 0^s.05$. Schott's value was based largely upon the result of the 1892 cable determination of the difference of longitude between Montreal, Canada, and Greenwich, for the result of which only the preliminary value was available when the adjustment was made. The definitive value gave a correction to the preliminary value of $-0^s.05$, indicating that Schott's value of the Washington-Greenwich longitude is somewhat too large. Assuming the value given above for the Greenwich-Paris longitude, and combining with it the Washington-Paris longitude resulting from the present determination, the following value is obtained for Washington-Greenwich:

$$5^h\ 8^m\ 15^s.721 \pm 0^s.014.$$

The French authorities have proposed that an extension of their first experiment be repeated with other stations, and it will be interesting to see how near the difference of longitude carried around the world will check up to 24 hours.

WEATHER REPORTS.

An important element in safe navigation at sea is information respecting weather conditions that may be expected within a certain region in which a ship is likely to find itself. Daily weather bulletins relating to the North Atlantic Ocean, the Gulf of Mexico, the Great Lakes, and the Pacific Ocean, prepared by the United States Weather Bureau, are sent broadcast by naval radio stations as follows:

The bulletins begin with the letters U.S.W.B. for the United States Weather Bureau, and the weather conditions follow. The first three figures of the report represent the barometric pressure in inches (0.02 = 30.02); the next figure, the fourth in sequence, represents the direction of the wind to eight points of the compass: 1 = north; 2 = northeast; 3 = east; 4 = southeast; 5 = south; 6 = southwest; 7 = west; 8 = northwest; and 0 = calm. The fifth figure represents the force of the wind on the Beaufort Scale, running from 0 = calm, to 12 = hurricane. In order to simplify the code, no provision is made for wind force greater than 9 = strong gale, on the Beaufort Scale.

If the weather conditions from any one station cannot be supplied, the initial of the station is given, followed by the word "missing," and if any portion of a report cannot be furnished, such portion is replaced by an equivalent number of letters x.

The second part of the bulletin consists of wind and weather forecasts and, whenever conditions warrant, information as to storm-centres, storm and hurricane warnings, and advices to shipping. The wind and weather forecasts are for 24 hours, beginning at midnight. The zones to which the forecasts apply are identified by suitable charts. Whenever a storm exists that is likely to affect a section, the location and expected direction of movement of the storm centre will be given, followed by any storm or hurricane warnings and advices to shipping that have been issued.

EXAMPLE OF BULLETIN:

(First part.) USWB J 01662 S 00663 FP 98821 ML 95427 T 95846 NY 93258 DB 92888 LB 95612 CH 94216 H 94645 AV 98282 C 96682 B 00661, etc.

(Second part.) Winds off Atlantic coast north of Sandy Hook will be shifting gales with rain. Sandy Hook to Hatteras, northwest gales with rains followed by clearing weather. Hatteras to Florida Straits, strong northwest winds; fair weather. Storm of marked intensity central off New Jersey coast moving northeastward. Storm warnings displayed Hatteras to Eastport.

The second part of the bulletin is always in plain language and requires no translation. Suitable charts show the location of many of the regular observation stations maintained by the Weather Bureau on the continent and in the Gulf of Mexico, and the Caribbean Sea, within the confines of the map; also Canadian stations. Key letters are indicated under station reports from which are given radio distribution. These reports, supplemented by others picked up from vessels, can be used, as illustrated on the chart, in the production of quite a comprehensive weather map, which will be of much value to navigating officers. Observations radiographed from vessels are in a code prepared by the Weather Bureau for "Vessel Weather Observers" and are easily translated by use of that code.

DISTRIBUTING STATIONS.

Atlantic Coast.

Following is a list of Naval radio stations from which distributions are made, and the composition of the bulletins distributed by them:

ARLINGTON, VA.: Sending time, a few minutes after 10 P.M., 75th meridian time. Wave-length, 2650 metres.

Observation stations contained in first part and code letters.		Second part of bulletin.
St. Johns, N. B.	J	(1) Winds off Atlantic coast north of Sandy Hook.
Sydney, N. S.	S	
Father Point, Canada	FP	(2) Winds off Atlantic coast, Sandy Hook to Hatteras.
Montreal, Canada	ML	
Nantucket, Mass.	T	(3) Winds off Atlantic coast, Hatteras to Florida Straits.
New York, N. Y.	NY	
Breakwater, Del.	DB	Storm warnings, Eastport, Me., to Key West, Fla.
Lynchburg, Va.	LB	
Cape Henry, Va.	CH	Location and expected direction of movement of storm-centres affecting Atlantic coast.
Hatteras, N. C.	H	
Asheville, N. C.	AV	
Charleston, S. C.	C	All hurricane warnings and advices.
Bermuda	B	Figures in brackets correspond to zones shown on appropriate charts.
Atlanta, Ga.	AT	
St. Louis, Mo.	SL	Period covered by forecasts, 24 hours beginning at midnight.
Little Rock, Ark.	LR	
Nashville, Tenn.	NV	
Duluth, Minn.	DU	
Marquette, Mich.	M	
Chicago, Ill.	CH	
Detroit, Mich.	D	
Buffalo, N. Y.	F	
Cincinnati, Ohio	CN	

This station broadcasts about noon, 75th meridian time, all storm warnings issued in the forenoon for the Atlantic coast and Great Lakes; also broadcasts at night (during the season of navigation on the Great Lakes) the same bulletin distributed by the Great Lakes station and at approximately the same hour.

KEY WEST, FLA.: Sending time, a few minutes after 10 P.M., 75th meridian time. Wave-length, 1988 metres.

Observation stations contained in first part and code letters.		Second part of bulletin.
Hatteras, N. C.	H	(3) Winds off Atlantic coast, Hatteras to Key West.
Charleston, S. C.	C	(4) Winds over east Gulf of Mexico (east of longitude 90°).
Jacksonville, Fla.	JA	(5) Winds over west Gulf of Mexico (west longitude 90°).
Miami, Fla.	MI	(6) Winds over Caribbean Sea (west of longitude 73°) and Windward Passage.
Key West, Fla.	K	Storm warnings Hatteras to Key West and for Gulf of Mexico.
Pensacola, Fla.	P	Location and expected movement of storm-centres affecting Atlantic coast south of Hatteras and Gulf of Mexico.
Burrwood, La.	BW	Storm warnings Gulf of Mexico, Key West to Brownsville.
Galveston, Tex.	GV	All hurricane warnings and advices.
Brownsville, Tex.	BV	Figures in brackets correspond to zones shown on appropriate charts.
Fort Worth, Tex.	FW	Period covered by forecasts, 24 hours beginning at midnight.
Kingston, Jamaica	KN	
Turks Island	TI	
Havana, Cuba	HA	
Guantanamo Bay, Cuba	GO	
Swan Island	SI	
San Juan, P. R.	SJ	

POINT ISABEL, TEX.: Sending time, midnight, 75th meridian time. Wave-length, 2250 metres.

Observation stations contained in first part and code letters.		Second part of bulletin.
Key West, Fla.	K	(4) Winds over east Gulf of Mexico (east of longitude 90°).
Tampa, Fla.	TA	(5) Winds over west Gulf of Mexico (west of longitude 90°).
Pensacola, Fla.	P	(6) Winds over Caribbean Sea (west of longitude 73°) and Windward.
Mobile, Ala.	MO	Storm warnings for Gulf of Mexico, Key West to Brownsville.
Burrwood, La.	BW	Location and expected movement of storm-centres affecting Gulf of Mexico.
Galveston, Tex.	GV	All hurricane warnings and advices.
Corpus Christi, Tex.	CC	
Brownsville, Tex.	BV	
Kingston, Jamaica	KN	
Swan Island	SI	

Figures in brackets correspond to zones shown on appropriate charts.
Period covered by forecasts, 24 hours beginning at midnight.

SAN JUAN, P. R.: Sending time, 9 P.M., 75th meridian time. Wave-length, 2750 metres.

Distribution is made from this station only from June to November, inclusive.

Observation stations contained in first part and code letters.		Second part of bulletin.
San Juan, P. R.	SJ	All hurricane warnings.
St. Thomas, Virgin Islands	ST	In the absence of a tropical storm the following words will be sent each day, "Weather Normal."
Basseterre, St. Kitts	BT	
Roseau, Dominica	RS	
Bridgetown, Barbados	BB	
Santo Domingo, S. D.	SD	
Puerto Plata, S. D.	SL	
Port au Prince, Haiti	HT	
Willemstadt, Curacao	W	
Port of Spain, Trinidad	PS	

Hurricane warnings also will be broadcast from this station at 10 A.M., 75th meridian time, or as soon thereafter as possible.

GREAT LAKES.

GREAT LAKES, ILL.: Sending time, shortly after 10 P.M., 75th meridian time. Wave-length, 1988 metres.

Distribution is made from this station only during season of navigation on the Great Lakes, approximately April 15th to December 20th.

Observation stations contained in first part and code letters.		Second part of bulletin.
Duluth, Minn.	DU	Forecasts for upper Lakes (Superior, Michigan, and Huron).
Marquette, Mich.	M	Forecasts for lower Lakes (Erie and Ontario).
Saulte Ste. Marie, Mich.	U	Storm warnings for upper and lower Lakes.
Green Bay, Mich.	G	Location and expected movement of storm-centres affecting the Lakes.
Chicago, Ill.	CH	
Grand Haven, Mich.	GH	
Alpena, Mich.	L	
Detroit, Mich.	D	
Cleveland, Ohio	V	
Buffalo, N. Y.	F	

Period covered by forecasts, 24 hours, beginning at midnight.

All storm warnings issued in the forenoon for the Great Lakes also are distributed from this station about noon, 75th meridian time.

Storm and hurricane warnings are displayed at over 200 points along the Atlantic and Gulf coasts, including every port and harbor of any considerable importance. Flags are used by day and lanterns at night. Illustrations and descriptions of these signals will be found on pilot charts.

Pacific Coast.

Weather bulletins are obtained from the Weather Bureau at San Francisco by the San Francisco station about 6 P.M., and forwarded by radio to North Head and San Diego as soon as practicable. San Francisco, North Head, and San Diego radio stations broadcast this weather bulletin on the working wave, 952 meters and 600 meters, immediately after transmission of time signals, etc. All stations broadcast hydrographic information and storm warnings immediately after receipt, and at 8 A.M., noon, 4 P.M., and 8 P.M. (four-hour intervals immediately after receipt of message, except 4 A.M. and midnight). All stations also broadcast their local weather at 8 A.M., noon, 4 P.M., and 8 P.M. Cape Blanco broadcasts weather conditions at Tatoosh, North Head,. and Eureka, immediately after broadcasting local weather report. At 8 A.M. and 8 P.M. Eureka broadcasts the 6 A.M. and 6 P.M. weather condition at Farallon Islands; Point Arguello broadcasts the 7 A.M. and 7 P.M. weather conditions at Farallon Islands; Farallon Islands broadcasts the 6 A.M. and 6 P.M. Eureka weather condition and the 7 A.M. and 7 P.M. Point Arguello weather condition.

The daily bulletin broadcasted by San Francisco, North Head, and San Diego, consists of two parts. The first part contains code words and figures which express the actual weather conditions at 5 P.M. (120th meridian time) on the day of distribution at certain points along the western coast of the United States. The second part of the bulletin contains a special forecast of the probable winds to be experienced a hundred miles or so offshore, made by the United States Weather Bureau, San Francisco, for distribution to shipmasters by naval radio as above. The second part of the bulletin also contains warnings of severe storms along the coast as occasion may arise.

The coast line of the western part of the United States is divided as follows:

Northern Pacific, Tatoosh to Cape Blanco.
Central Pacific, Cape Blanco to Point Arguello.
Southern Pacific, Point Arguello to San Diego.

The forecast and warning is in ordinary language, and covers a period of 24 hours from 5 P.M., date of issue. At the end of the forecast a statement is made in regard to the location and movement of any barometric depression that may be likely to affect the winds over the ocean.

Example of forecast and warnings:

> Northern Pacific missing Central Pacific Wednesday rain heavy southeast winds Southern Pacific moderate southerly winds period Southeast storm warnings displayed Pointarguello to Capeblanco.

A new broadcasting service for the Pacific Coast is being arranged.

Hawaii.

Weather bulletins obtained from the United States Weather Bureau at Honolulu are broadcasted daily by the Pearl Harbor Radio Station at 8 A.M., noon, 4 P.M., and 8 P.M.

Tutuila, Samoa.

Local weather bulletins preceded by the letter " T " are broadcasted by the Tutuila Naval Radio Station at 8 A.M., noon, 4 P.M., and 8 P.M.

HYDROGRAPHIC INFORMATION.

Information concerning wrecks, derelicts, ice, and other dangerous obstructions to navigation whenever received from the Hydrographic Office or from a branch hydrographic office or other reliable source is sent broadcast four times daily, viz, at 8 A.M., noon, 4 P.M., and 8 P.M., local (standard) time of station. Ships within range of a naval radio station receive these hydrographic messages and refrain from sending radio messages at these times, knowing that one vessel sending may prevent several others receiving information necessary to their safety.

Naval radio stations furnish this information to passing vessels on request, at other hours than those mentioned. Should it not be practicable to send out this information on one of the hours mentioned, it is held until the next scheduled time and then sent broadcast.

Each day at noon, and at 10 P.M., 75th meridian time, immediately following the time signal, the Naval Radio Station at

Washington broadcasts such information relating to safe navigation as may be furnished it by the Hydrographic Office during the preceding 24 hours. The same wave-length, 2650 metres, used in the time signal, is employed.

In addition to the regular hydrographic information sent out from naval radio stations as a daily routine, special provision is made during the Spring months for furnishing information relating to the location of icebergs that drift from their northern breeding grounds, and which are liable to drift in the lanes of passenger steamers to and from Europe in the North Atlantic.

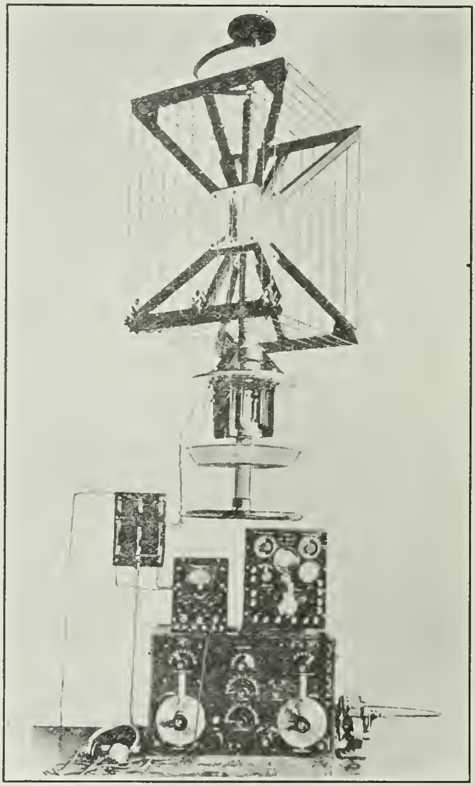
By a special agreement reached at the International Convention on Safety of Life at Sea, which met in London in the Fall of 1913, the United States obligated itself to cause a sea patrol to be kept in the steamship lanes where icebergs are liable to be found, and to report the presence and location of these icebergs to nearby vessels by proper radio reports. In addition to these reports, at least one daily report of icebergs is sent to Washington by radio either through Canadian or United States stations, and these in turn are broadcasted at stated intervals for the benefit of shipping that cannot be reached by the patrol vessel. All countries signatory to the Safety at Sea Convention bear their proportionate shares of the expense connected with this patrol. This patrol has been of the greatest help to mariners, and more than one vessel owes its safety to information given by the patrol vessel. By giving the exact location of dangerous icebergs, vessels are enabled to steer a course that will safely lead them from danger.

THE RADIO DIRECTION FINDER.

The name "Radio Direction Finder" is a name applied to certain electrical apparatus which is so constructed as to enable its operator to discover from what direction a given radio signal emanates. This apparatus is sometimes referred to as a "Radio Compass."

A few words illustrating the elementary principle upon which the radio compass functions may be desirable. If we imagine a vertical conducting wire as the antenna of a radio transmitting set, this will, on being properly energized, radiate a series of electric magnetic waves which may, for purposes of illustration, be considered as a series of concentric circles radiating from the conductor as a circle, or, in other words, the lines representing the waves are closed circles. They expand at the speed of light and finally reach the receiving antenna of the radio compass.

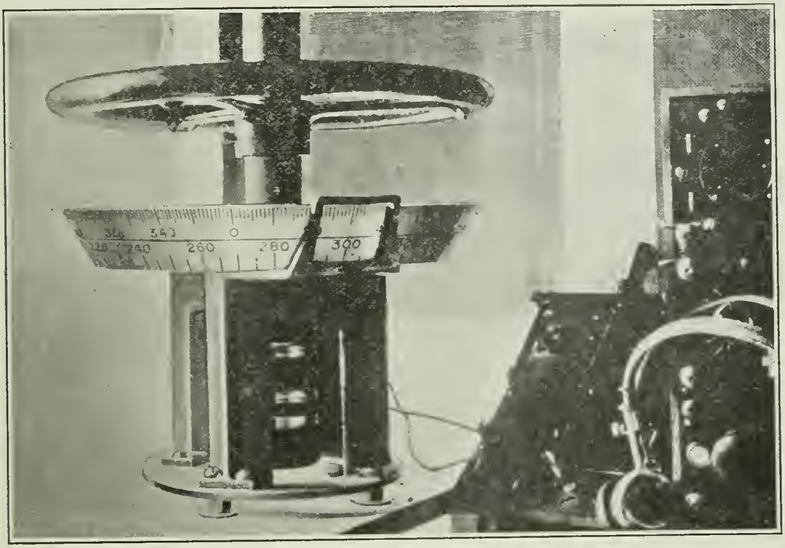
From the well-known electrical theory that when a coil of wire is placed in a varying magnetic field, an E M F will be induced in the coil, and if the circuit is closed a current will flow, the magnitude of the induced E M F will depend upon the number of lines of force that are actually cutting through the coil. If the coil is placed so that the magnetic lines go through it in a direction parallel to the turns of the coil, there will be no induced E M F, since there are no magnetic lines actually cutting through it. If, however, the coil is turned so that the magnetic lines thread through the coil in a direction at right angles to the turns of the coil, induction in the coil will be a maximum. The induced



Radio compass receiving equipment.

E M F will tend to drive a current through the coil if the circuit is closed. In order that the presence of this current may be manifested, suitable means for tuning the circuit to make the current a maximum and for detecting it must be provided. Tuning may readily be accomplished by placing a condenser across the terminals of the receiving circuit.

Associated with the coil and the capacity across its terminals, is the receiving circuit, generally of a vacuum tube in connection with the head telephones. If the coil is so arranged that it may be rotated, there will be a position where there are no lines of force actually cutting the coil, there will be no induced E M F and no signal will be heard in the telephone. If the coil is turned through 90°, the number of cutting lines of force will be a maximum, and the signal heard in the telephone will be a maximum. This furnishes a ready means for determining the direction of the incoming signal. It will be seen that as the coil is rotated, there will be two positions of minimum signals and two of maximum, the minimum being 180° apart and the maximum 180° apart. If the minimum is taken as the point of observation, it is known that the transmitting station is in a direction at right angles to the plane of the coil when in the position corresponding



Close view of compass scale.

to minimum signals. The compass used in this manner determines one line of hearing, in which the ship emitting the signal must be. The general configuration of the land and surroundings determines which of the two bearings 180° apart is the one to be used. This method of operation is termed "bilateral," in which the signal strength undergoes the same variation twice in a complete revolution.

By obtaining two or more lines of bearing from separate stations, a ship's position is obtained by noting the intersection of the lines of bearing from each. If the apparatus is so arranged that one of the maxima is louder than the other, we may take either the louder or weaker maximum as the true direction of the ship's transmitter. If the coil is placed in a position corresponding to a signal of maximum intensity, with the plane of the winding parallel to the direction of the transmitter, an arrow may be attached to one side of the coil to aid in identification of this side. Now the coil may be completely turned around through 180°. The plane of the coil is again parallel to the original direction and the current of the coil is now at maximum, but is now flowing through

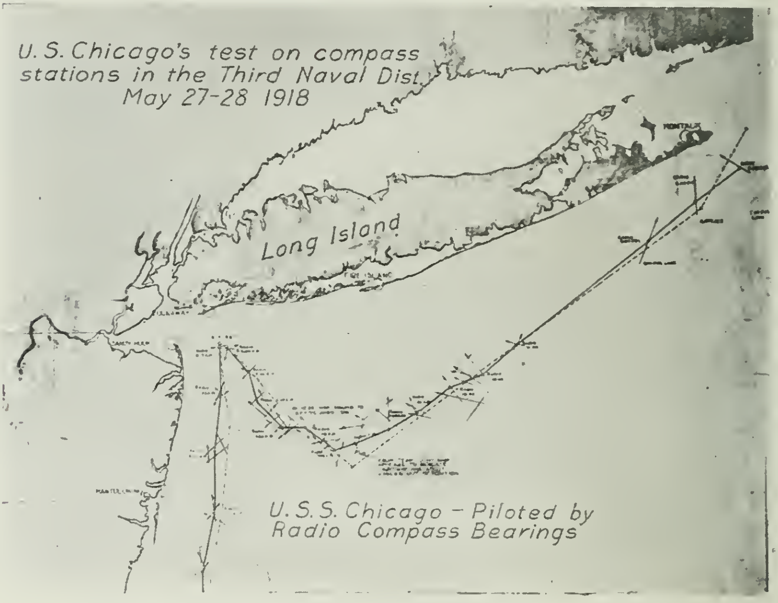
Bearings are quickly plotted at central control shore station before being forwarded to vessel concerned. This to assure precision.

the circuit in the reverse direction. The only effect of reversing the coil is to reverse the direction of the current flowing through it; the signal strength remains the same. If it were possible to rotate on its axis a single wire forming the antenna, it would be found that the strength of the received signals remained the same, or, in other words, that the signal strength does not depend in any way upon the direction of the transmitting station. Such a system may be appropriately termed a non-directional system. If we have another current which does not reverse when the coil is reversed, the two currents will add in one position and in the other position will subtract. One maximum is thus strengthened and the other is weakened.

The unilateral method determines very roughly the absolute direction of the transmitting station, or, in other words, gives us the sense of direction. The readings may not be taken with any degree of accuracy, since the maxima are not well defined.

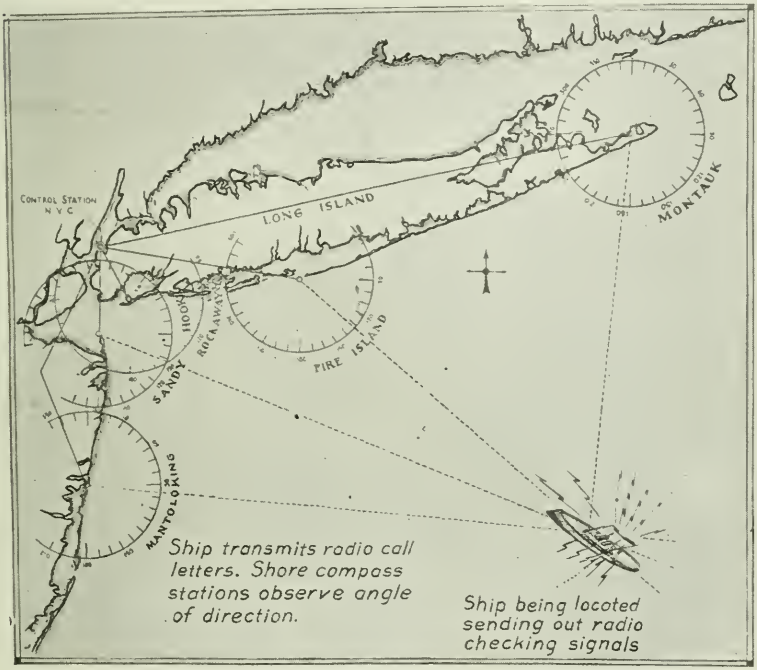
A combination of the two methods results in ideal operation, since one type balances up the weak points of the other. The general sense of direction is obtained with the unilateral, the antenna circuit is then disconnected and the bilateral method gives the accurate bearing. The information obtained with the unilateral method enables us to discard one of the maxima on the bilateral, giving the remaining maximum as the absolute direction of the transmitter. The general arrangement of the compass coil, with the necessary receiving attachments, is shown in the figure.

The perfected system of radio direction finding has been in use in the American Navy for a little over a year. A brief description will be given of the method of its use in a crowded neighborhood, as is found off the port of New York. It is assumed that a ship is off the port 80 or 100 miles, and maybe is in a doubtful position. The ship emits a signal by her radio "QTE" which, interpreted, means, "What is my true bearing?" This request, coming within the sector which the New York District Central Controlling Radio Station is responsible for, the appeal is received by five radio compass stations located at Montauk Point, L. I., Fire Island, Rockaway Beach, Sandy Hook, and Mantoloking, N. J., which are shown in the figure. Each of these stations is connected with the New York Central Control Office, at 44 Whitehall Street, by telegraph and telephone. These radio compass stations can not communicate with a ship, as they have receivers only, and not transmitters. Each of the radio compass stations notifies the Control Station in Whitehall Street that a ship is asking for bearings. Immediately the Control Station radios to the ship to continue sending the ship's call letters for about 30 seconds. During this interval the radio compass stations begin obtaining bearings on the ship. The operators in the five stations turn their compass coils until each has an accurate bearing. These five readings are transmitted to the central station, where, on a large chart, the five readings are combined and plotted. At the point of intersection of the various lines of bearing is the location of the calling ship. The main control office then transmits to the ship its bearings from each of two or more stations and the navigator on the ship can then plot his own bearings, find the intersection and know where the ship is located. Acknowledgment from the ship completes the operation, and the ship will then be able to set a safe course and proceed on its way. Various pictures are shown on the screen showing this operation.


U. S. Chicago's test on compass stations in the Third Naval Dist. May 27-28 1918
Long Island
U. S. S. Chicago – Piloted by Radio Compass Bearings

Comparison of positions plotted by radio bearings with actual positions.

These radio compass stations are now installed on the Atlantic, Gulf, and Pacific coasts, as well as on the Great Lakes, and stations are being constructed in Alaska and in all outlying possessions. There are at present 47 compass sections built and ready for operation, and 27 more under construction. A general plan of the location of these stations is shown in the picture on the screen, showing how well our coasts are protected by these safety devices. There will be shown one or two examples of this operation and the great use it has been to mariners in saving lives and property. Also there is shown the track of a ship that made a voyage along the coast from Boston as far south as Charleston, with her course accurately plotted by other navigational means than the radio compass, and during this trip the ship was located by radio compass bearings from various stations, which are also shown on the chart, showing how well these compass stations were able to keep track of the ship during this journey. The distance at which bearings are accurate within say half a degree, is probably at this time limited to distances between 75 and 100 miles, but constant improvements are being made, and as the skill of the operators increases, it is readily expected that these distances will be easily doubled with the same degree of accuracy.



Ship transmits radio call letters. Shore compass stations observe angle of direction.

Ship being located sending out radio checking signals

Graphic representation of method used for obtaining radio compass bearings.

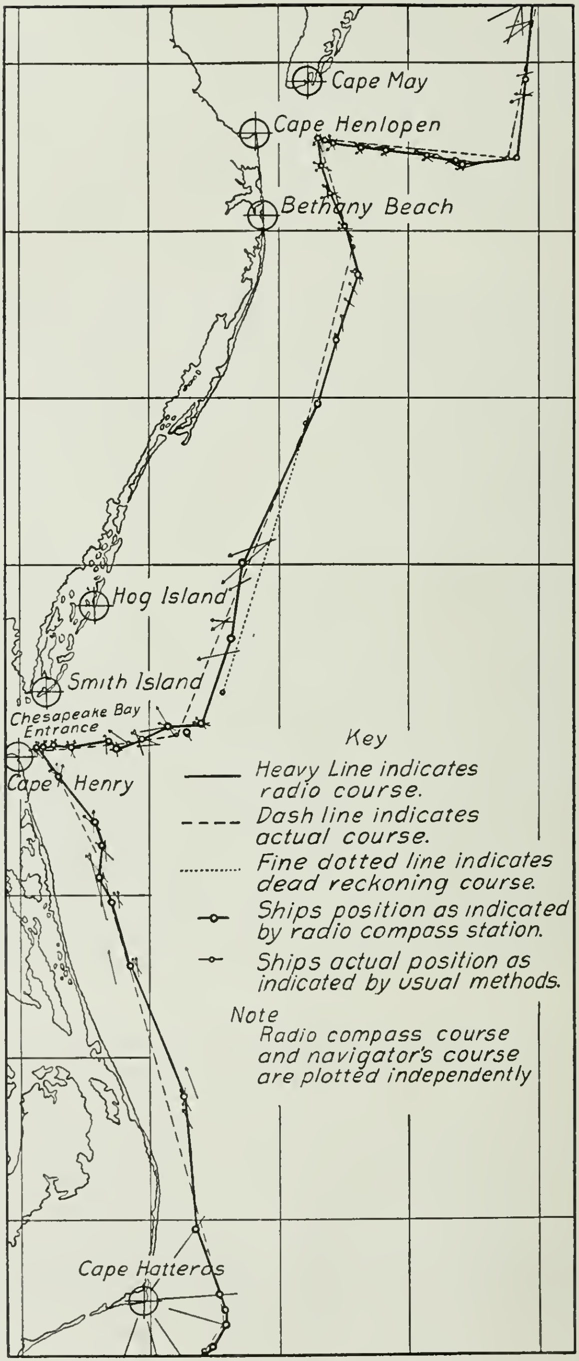

Cape May
Cape Henlopen
Bethany Beach
Hog Island
Smith Island
Chesapeake Bay Entrance
Cape Henry
Cape Hatteras
Key
Heavy Line indicates radio course.
Dash line indicates actual course.
Fine dotted line indicates dead reckoning course.
Ships position as indicated by radio compass station.
Ships actual position as indicated by usual methods.
Note
Radio compass course and navigator's course are plotted independently

Chart showing test of radio compass shore stations by U. S. S. *Chicago*, Boston, Mass., to Charleston, S. C., May 26th to May 30th, 1919.

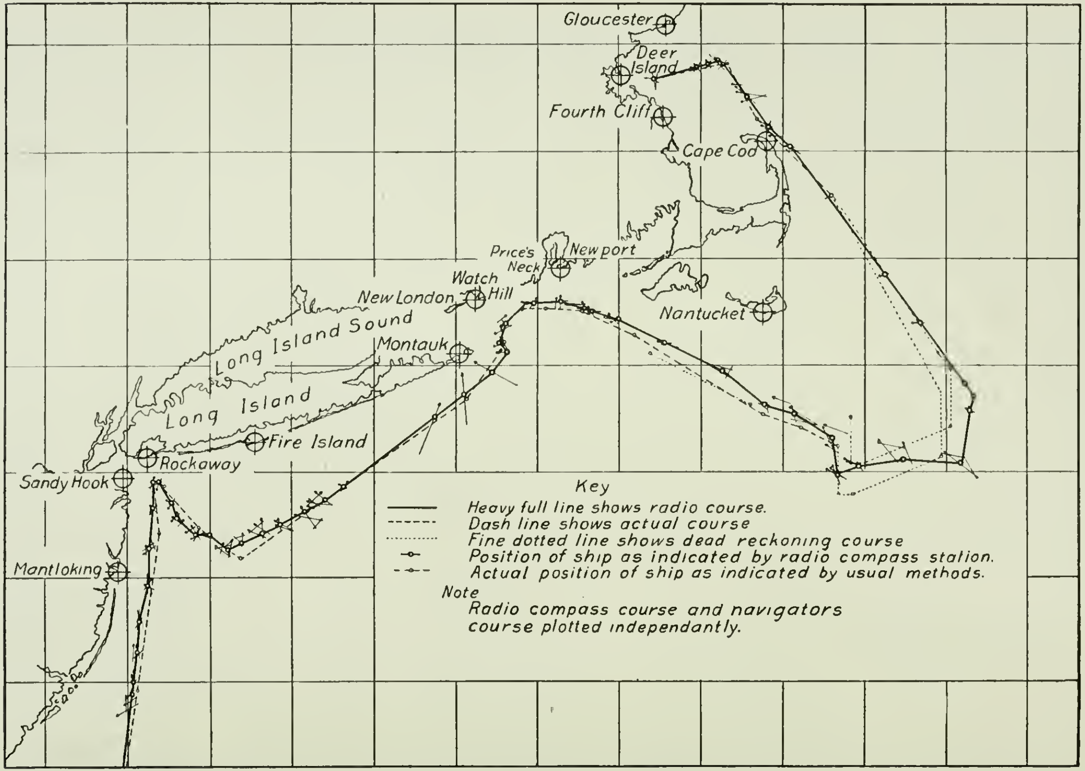

Gloucester
Deer Island
Fourth Cliff
Cape Cod
Price's Neck
New port
Watch Hill
New London
Nantucket
Long Island Sound
Montauk
Long Island
Fire Island
Rockaway
Sandy Hook
Mantloking
Key
Heavy full line shows radio course.
Dash line shows actual course
Fine dotted line shows dead reckoning course
Position of ship as indicated by radio compass station.
Actual position of ship as indicated by usual methods.
Note
Radio compass course and navigators course plotted independantly.

Chart showing test of radio compass shore stations by U. S. S. *Chicago* Boston, Mass., to Charleston, S. C. May 26th to May 30th, 1919.

In addition to shore stations being fitted as radio compass stations, naval ships themselves are also fitted with this apparatus, by means of which they are enabled to obtain the direction of various short stations, and thus easily locate themselves, and are enabled to pick up the bearings of other ships that may be in the neighborhood.

The radio compass finds especial use with aircraft, and aircraft may be safely navigated in flight, by giving them their bearings from shore stations. Similarly, aircraft may locate ships at sea by means of their radio compasses.

On July 6, 1920, a seaplane flight was made to demonstrate the reliability of aircraft navigation by use of radio compass. The seaplane was based at the Naval Air Station, Hampton Roads, and worked in conjunction with the U.S.S. *Ohio,* which is especially fitted as a floating radio laboratory for purposes of conducting tests and carrying on radio experiments. At the start of the flight the seaplane knew nothing as to the location of the *Ohio,* further than that the ship was in an arc of 100 miles centered at Norfolk. Just 5 minutes after the start of the flight an accurate radio compass bearing of the ship was secured, and 1 hour and 30 minutes later, the seaplane, after having flown 85 miles almost direct, circled the *Ohio.*

The *Ohio* was under way to the southward, as shown by the bearings obtained by the seaplane. The navigation, on the return flight to Norfolk, was accomplished by taking bearings on the Norfolk radio station, and which proved to be very accurate.

During the flight communication was maintained at all times with the following stations: The U.S.S. *Ohio,* the Naval Air Station, Anacostia, D. C., and Naval Operating Base, Hampton Roads, Virginia.

In addition, the radio compass stations at Cape May, N. J., and Bethany Beach, Virginia, took cross-bearings on the seaplane, and these proved to be very accurate. The plane also took bearings on Cape May, which proved equally accurate. The Naval Air Station, Anacostia, obtained compass bearings on both the *Ohio* and seaplane, during the entire flight, and later it was possible to plot the approximate courses of both ship and plane.

On the return flight from Norfolk, on July 7, bearings were taken on the *Ohio* by the plane at a distance of 175 miles, which is probably a record for this class of work, but greater distances can be obtained by increasing the power of the transmitting station.

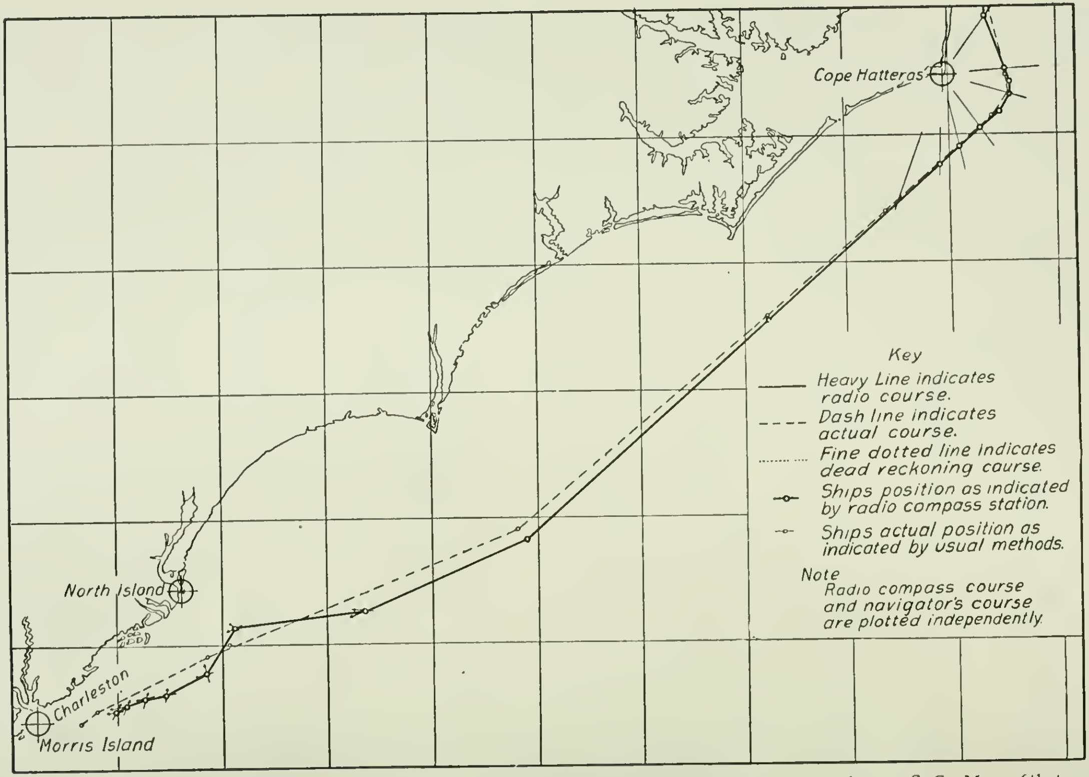

Cope Hatteras
North Island
Charleston
Morris Island
Key
Heavy Line indicates radio course.
Dash line indicates actual course.
Fine dotted line indicates dead reckoning course.
Ships position as indicated by radio compass station.
Ships actual position as indicated by usual methods.
Note
Radio compass course and navigator's course are plotted independently.

Chart showing test of radio compass shore stations by U. S. S. *Chicago*, Boston, Mass., to Charleston, S. C., May 26th to May, 30th, 1919.

The Aircraft Radio Laboratory has completed experiments and has found that the bearings from aircraft when observed by shore radio compass stations are accurate to within two degrees when aircraft are beyond a distance of 20 miles from compass stations, but that when aircraft are within a distance of 20 miles from shore compass stations, bearings vary considerably. In this experiment it was noted that when they received short wave signals, when aircraft was flying directly overhead, there was apparently a zone of silence from aircraft, and that when aircraft was receiving from a shore station transmitting, the effect was reciprocal. In other words, when aircraft flew over a transmitting station which sent signals on short wave lengths, there was a zone of silence directly over the station, and it has been suggested that this zone of silence could be used to advantage as a landing field indicator. As aircraft approaches a landing station and is receiving bearings from it, it may find itself in this zone of silence, when it will be known that it is directly over the station, and thus has positive information of its location. This should be very useful in thick or hazy weather.

The radio compass was very successfully used during the war to determine the presence of hostile ships, particularly submarines, which had a habit of coming to the surface at night and endeavoring to communicate with their home bases at night, by radio. The moment the radio started, compass bearings were obtained from one or more stations, and in this manner the location of these hostile submarines was known, and their track could almost be definitely followed. This resulted in time in the capture or destruction of many enemy submarines, until they became certain that some means unknown to them was being used against them and had no alternative but to keep silent, thus being lost track of by their home bases.

DIRECTING SHIPS THROUGH NARROW CHANNELS BY THE DIRECTIVE PILOT CABLE.

In speaking of this subject, I feel it is desirable to call the attention of the audience to the fact that it is believed that the Secretary of this Institute, Major Owens, was the first to make practical use of the principles involved, and he held the original patent in this country concerning this very useful feature of safe navigation.

This operation of pilot directing involves the laying of a cable in channels where it is proposed to be used, such as the main channels leading to our various large ports. It found extensive use during the war in laying cables through dangerous mine fields, and afforded a means of safely conducting ships through these dangerous localities in safety.

The radio piloting cable as recently demonstrated by the Navy Department in New York harbor, may be described as follows:

A rubber insulated cable having an internal conductor of seven strands, No. 16 copper wire, and an external armor of No. 12 galvanized steel wire, was laid from Fort Lafayette in the Narrows to a point approximately 1900 yards from the Ambrose Channel Light Vessel. This cable was laid exactly in the middle of the channel, the depth of which varies from 40 to 100 feet. The internal conductor of this cable is connected at the Light ship end of the cable to the armor and current is supplied to the cable by a 1-kw., 500-cycle alternator at Fort Lafayette.

The internal conductor of the vessel is connected through an automatic key and inductance to one terminal of the alternator, while the other terminal of the alternator is connected directly to the armor. The current as transmitted into this cable by means of the automatic key flows out through the inner conductor to the extreme end of the cable and then returns by way of the armor and also the surrounding salt water. The total length of this cable is 87,000 feet, while the impedance of the cable is 123 ohms. For best operating conditions a current flow of 3 amperes at 325 volts is supplied to this cable.

The equipment for receiving signals from this cable on board consists of two coils of wire placed on opposite sides of the ship approximately amidship and above the water line. These coils at the present time contain 400 turns of wire wound on a form four feet square. Leads from these coils are run to a double-pole, double-throw switch on the bridge of the vessel, by means of which electric energy as received from the cable can be transferred to a two-stage audio frequency amplifier. Connected to this amplifier are the regular Navy Standard Telephone Receivers. The action of the receiving apparatus is similar to ordinary electrical engineering wherein current flow is produced in a closed electrical loop when the loop is brought under the influence of a pulsating magnetic field. When the vessel is approximately directly over the cable, the same electro motive force will be induced in each coil, therefore indicating in the telephone receivers on the head of the pilot an equal signal strength from each coil. Should the vessel move to the right or to the left of the cable, there will be a difference in the received signal strength as noted by the different coils, due to the fact that the coil nearest the cable will receive the maximum signal while the coil that is farthest away from the cable will receive the minimum signal.

During the demonstration test conducted during the week of October 4, 1920, it was found that readable signals were obtained from the cable when the destroyer *Semmes* was 1100 feet to the right or to the left of the cable, in this case the distance is approximately 50 feet outside of the channel buoys.

It was also found during these tests that very little experience was required for the average seafaring man to familiarize himself with this equipment and to safely pilot vessels through the Ambrose Channel, even when persons were blindfolded. Three seafaring men, two of which were local pilots and the other a captain of the Cunard Liner *Virgilia*, successfully piloted the destroyer *Semmes* through the Ambrose Channel at the speed of ten knots. These men had never seen this equipment before, but after one-half hour's instruction were able to take the control of the ship and relieve the captain of the duties of navigating the vessel. There were approximately 139 prominent people to witness these tests and of that number there was no person who found fault with this system, and upon being questioned were thoroughly in favor with the assertions made as to the future possibilities of this system. Before leaving the destroyer *Semmes* they thanked the Navy officials for having brought to their attention the possibilities of this new aid to navigation.

APPLICATION OF RADIO COMPASS TO DETERMINE PRESENCE OF THUNDERSTORMS AND FORECASTING THEIR PRESENCE AND APPROXIMATE LOCAL DIRECTION.

The radio telephone set has proven itself of immense value in detecting the approach of and recession of thunderstorms. With increasing static in a radio telephone set, an observer is able to determine a storm's approach, while decreasing static indicates the breaking up of the disturbance or its movement farther away from the station. Storms that were 50 to 150 miles away have been detected in this way. On one occasion an observer heard static about 3.30 P.M., which increased until 6.00 P.M., and then decreased until 8.00 P.M., when the sky became clear. Upon translating code words received from the Weather Bureau, it was learned that a thunderstorm had occurred in a neighboring locality that exactly fitted the conditions observed in the static observations. An observer soon becomes accustomed to various static intensities and variations. Looking at distant lightning on a cloudy night, and at the same time noting the various grades of static, is the ideal way to get training with this device. By noting the time by stop watch between heavy growls of static and time thunder is heard, an observer can get an idea as to the distance of the storm from flashes that would ordinarily be hidden from view. This device is very useful for detecting storm static when hurricanes are in the Gulf of Mexico.

The following important facts have been noted, which are considered worthy of attention of all naval operators, and particularly aircraft operators:

1. Increasing local static denotes the approach of thunderstorms. If static is heavy the showers and squalls attending the storm will be heavy, and severe lightning may be expected. If the static is weak rains will be light to moderate, and without squalls;

2. Increasing, stationary, then decreasing static, denotes that disturbance is approaching, passing by, and moving away; in these cases the clouds may or may not show along the horizon as the storm passes;

3. The direction of the storm may be obtained by the radio compass;

4. It is thought that distant storm static may be detected by operators at radio compass stations, and the position of storms at sea obtained by interception of azimuth bearings given and storm's position charted frequently to obtain its force and future course, and give warning to interests involved.

5. It is probable that tropical hurricanes may be detected and movement shown through Caribbean Sea and Gulf of Mexico.

6. It may be difficult to get static from winter cyclonic storms and storms in the North Atlantic, on account of the absence of electrical disturbances attending them.

USE OF RADIO APPARATUS IN CONNECTION WITH WEATHER FORECASTS.

In order to use radio for detection of storms, and in a general way to give forecasts of the direction and proximity of storms, the following observations are given by which the presence of static in the receivers of radio apparatus can be used to advantage in weather forecasting.

Case A.—Reception from ordinary antenna, where no radio compass is installed.

Any unusual or sudden change in character or intensity of strays can be observed by radio operators and recorded in the log. A rapid rise in strays on short wave lengths usually indicates the approach of a storm, or at least a sudden change in the weather conditions. This does not mean that the usual increase in strays which comes after sunset in summer has any particular significance, unless the increase is abnormal and much longer than usual. When a storm is very close it is, in summertime, almost invariably preceded by a great increase in strays on short waves. The character of the strays gives some clew to the nature of the weather disturbance. A continuous succession of grinders seems usually to be followed by a general change in weather conditions, from fair or quiet, to unsettled and stormy. The storm centre may be at a considerable distance, but if there is a rapid increase in the whip-crack variety of strays, it is practically certain that a fairly violent electrical disturbance, which means a storm of considerable magnitude, is approaching.

Case B.—Observations at radio stations on ship or shore where radio compasses are installed.

In addition to the observations indicated in the preceding paragraph, the operator in charge of the direction finder is usually able to determine the line along which the storm is approaching, as the strays will be much weaker in certain positions when direction finder coil is turned than in others. In other words the strays will show a minimum, the same as a signal does, though not nearly so marked, as the strays do not come from one particular point, but from a general storm area. If the strays do not show themselves to be weaker in some directions than in others, it may be inferred, if they are exceptionally strong, that the unsettled weather conditions are pretty general and that no local violent storm is in progress. In the case of a local violent storm approaching from a distance, say inside of 50 miles, the whip-crack variety of strays which will be sure to precede it will certainly show a pronounced favorite direction. It is usually possible to determine within 30° and sometimes closer the line along which a disturbance is approaching. If, for instance, the strays are at a minimum, with the pointer of the compass at 90°, they will also be at a minimum at 270°. The choice between these two directions, diametrically opposed, will have to be determined by general weather conditions, unless the operator is provided with a one-way compass. He cannot determine from which direction strays are coming, that can merely get the line. This information should be of considerable value, if carried out by experienced operators.

GENERAL METHODS OF SIGNALING BY RADIO AT SEA.

The general method of synchronous signaling is eliminated in cases where sounds or signals are made simultaneously in the air or underwater. Thus if a vessel, a lightship, for example, is so arranged that it will emit a sound in the air such as is caused by a steam whistle, and a sound under the water is emitted say by a stroke on a bell, the sounds will reach an observer at different times, depending upon the relative velocities of air and water. If this interval between the sounds can be noted by a stop watch, the distance from the signaling stations can be readily obtained. If a sound signal in the air is replaced by a radio signal, a simple means is at once found to obtain the required distance from source of sounds. Thus, if an arrangement is made so that a radio dot is sent out at intervals of about .6 of a second, a submarine bell stroke being sent at the same time, the latter lags the interval between two dots for about each half sea mile traveled. If the ship is five miles from the sending station, the sound lags five times the interval, and the bell comes in on the 10th dot, supposing the 1st radio dot is emitted .6 of a second later than the 1st bell stroke. In this case it is only necessary to count up the number of radio dots and count the number of half sea miles separating the ship from the signaling station. By interpolation it is quite possible to tell when the bell stroke falls somewhere between two consecutive radio dots, and an estimation to the ¼ sea mile is feasible.

The Fessenden oscillator has long been a rival to the undersea bell as a means of sending sound waves in water, and it seems highly probable that on large ships it will take the place of the bell. As the result of an experiment, claims have been laid to: (1) Increased radius of audibility up to 30 miles or more; (2) Easy signaling over these distances of Morse code, by ordinary telegraph key; (3) Reception and emission of signals by one and the same apparatus, located in a ship or lowered overboard; (4) Determination of depth beneath the moving vessel by echo from the bottom; (5) Location of icebergs by reflected sound from submerged part of the berg.

Other uses of radio to warn mariners of danger into which they may be running, are provided by small radio telephone sets located at important points. Thus, by a phonographic arrangement connected with an automatic radio telephone set, constant words may be spoken by the set, which carries over a certain determined range, which is greater than the visible range. Thus, at Point Judith, an arrangement of this kind was made so that the intensity of the sound and radiation of the transmitter were so decided that ships equipped with the ordinary antenna would hear the signals the same approximate distance that light could be seen in clear weather. The automatic arrangement emits the name of the station every 5 seconds. When that is first heard the observer knows that he is about the same distance from the station that he would view the light in in clear weather. As the ship approaches the station, another automatic signal, which is continually being given out, but which is only heard at a reduced distance, gives a speech something like this: "You are getting closer! Keep off!" This indicates that the ship is too close to the sending station and must change her course to increase the distance. This signal also should only be heard at a certain distance, which the navigator knows. This instrument has been called the radio phone and it is intended to set up several of these radio phones at different stations on the Atlantic and Pacific coasts. These radio phones used in connection with a radio compass abroad ship, readily enable the navigator not only to obtain his bearing from the sound, but also his approximate distance.

Ships fitted with electric oscillators may readily communicate with one another by underwater signals in thick or foggy weather, when they cannot be seen by one another. Each ship may then signal to the other its course and speed, and each ship individually receiving this information can form a reliable estimate of the bearing of the others and the relative distances by the varying intensity of signals, and thus more readily maneuver in order to avoid collisions.

DETERMINATION OF DEPTH OF WATER.

One of the most recent developments in the use of varying sound-signaling and listening devices installed on ships of the Navy, has been the development of a means of finding the depth of water under a ship without the use of any mechanical devices. It is believed that this was first noted in March, 1919, on board the U.S.S *Von Steuben,* while making her first trip from Hoboken to Brest after having been equipped with an electrical hydrophone. The discovery resulted from the fact that the propeller sounds of other vessels, and, in fact, of the *Von Steuben* herself, could not be heard in water over 1000 fathoms deep. This fact led to the conclusion that the only propeller sounds that affected hydrophones were those that suffered reflection from the sea bottom. Sounds from a source such as a propeller reach the hydrophone receiver, which may be installed near the bow, by three different paths, namely, from reflection from the surface of the water, directly through the water in a straight line, and from reflection from the bottom. If the distance from the source of sound, the propellers to the hydrophone, is relatively great with respect to the distance the propellers are beneath the surface, then two of the paths, directly through the water and reflection from the surface, are nearly equal. The reflection from the surface being from a rare to a dense medium, introduces a change of phase of one-half the wave length, and as a result, the sound which travels directly from the propellers to the hydrophone, and that which is reflected from the surface, will give almost complete interference at the receiver. The only sound heard then, will be that reflected from the bottom. Since the only propeller sounds heard by the hydrophone located at a distance and near the surface is the component reflected from the sea bottom, it follows that the depth of water can be determined from the angle which the reflected sound makes with a fixed line in a plane determined by the sound time and the reflected rate, provided the distance between the hydrophone and the source of sound is known. Conversely, the distance between the hydrophone and the sound source can be determined if the depth of water is known. This last is of great importance in determining the distance of other ships, by means of the hydrophone, provided depth of water is known. The depth of water may be calculated from the following simple formula:

$$D, \text{ depth}, = C + L \tan \phi.$$

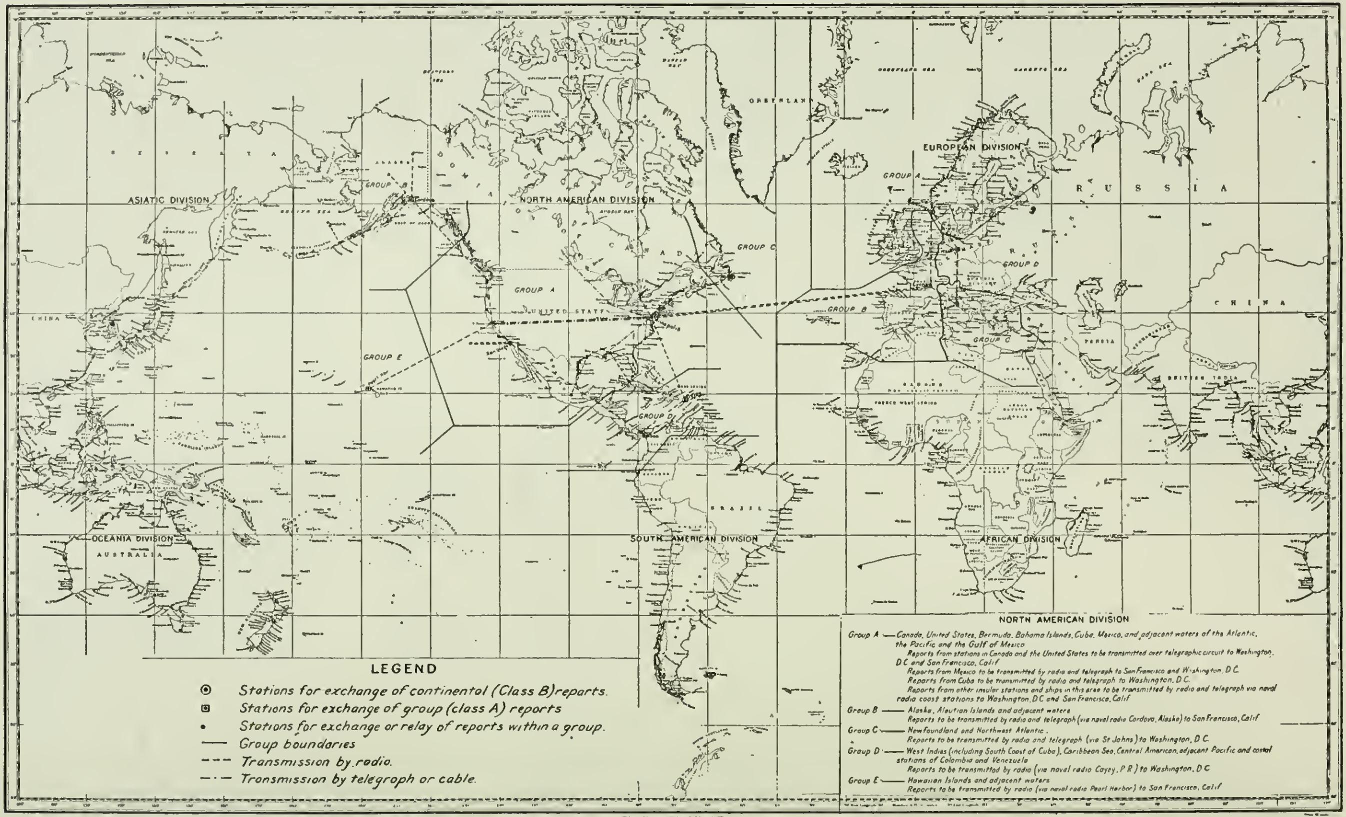
Where D represents depth, C is distance of sound producer below surface and $2L$ is distance between propeller and hydrophone. The angle ϕ 5 is referred to as sounding angle and is the supplement of angle theta, θ, which is the angle sound makes with ship's keel extended forward. Some errors are introduced in this by the character of the bottom, depending upon rapidity with which the depth of bottom changes and its slope, but, as an average, this method gives results which coincide very accurately with measured distances. It can readily be seen that if the depth is known the distance between the source of sound on one ship and a receiver on the other can be made the means of determining the distance between ships, which, in thick weather, is very desirable. This method of obtaining depth has been repeatedly checked with hand leads and general sounding machines in use at sea, and has been found to give very accurate results. It can be carried on at any speed, so it is shown that a ship fitted with a hydrophone can know at any time what is the depth of water under her, and furnishes ready means of keeping shipping out of dangerous waters. It will also readily be seen how the application of this principle of sound reflection can be used to determine the presence of any submerged object.

INTERNATIONAL METEOROLOGICAL REPORTS.

Many countries make provision for some sort of meteorological report to be broadcasted to sea by radio for the benefit of shipping in the immediate vicinity, and nearly every country has developed some sort of meteorological reports for the purpose of forecasting local weather. The United States has a highly developed service, both for local forecasting and for transmitting reports to ships and aircraft, by radio, and which has been previously described.

For a long time there have been serious attempts made to create an international weather reporting service, based on similar lines of procedure, using a common code that could be used alike for ships and aircraft. The development of the aircraft service and particularly that part which involves international flying,

INTERNATIONAL METEOROLOGICAL SERVICE



LEGEND

⊙ Stations for exchange of continental (Class B) reports.
◘ Stations for exchange of group (class A) reports
• Stations for exchange or relay of reports within a group.
— Group boundaries
--- Transmission by radio.
-·- Transmission by telegraph or cable.

NORTN AMERICAN DIVISION

Group A — Canada, United States, Bermuda, Bahama Islands, Cuba, Mexico, and adjacent waters of the Atlantic, the Pacific and the Gulf of Mexico
Reports from stations in Canada and the United States to be transmitted over telegraphic circuit to Washington, D C and San Francisco, Calif
Reports from Mexico to be transmitted by radio and telegraph to San Francisco and Washington, D C.
Reports from Cuba to be transmitted by radio and telegraph to Washington, D C.
Reports from other insular stations and ships in this area to be transmitted by radio and telegraph via naval radio coast stations to Washington, D C and San Francisco, Calif

Group B — Alaska, Aleutian Islands and adjacent waters
Reports to be transmitted by radio and telegraph (via naval radio Cordova, Alaska) to San Francisco, Calif

Group C — Newfoundland and Northwest Atlantic.
Reports to be transmitted by radio and telegraph (via St Johns) to Washington, D C.

Group D — West Indies (including South Coast of Cuba), Caribbean Sea, Central American, adjacent Pacific and costal stations of Colombia and Venezuela
Reports to be transmitted by radio (via naval radio Cayey, P R) to Washington, D C

Group E — Hawaiian Islands and adjacent waters
Reports to be transmitted by radio (via naval radio Pearl Harbor) to San Francisco, Calif

rests almost entirely primarily on the establishment of a successful international system of transmission of weather intelligence, based on a common, uniform practice.

One of the first attempts to produce an international system of weather reporting fell to the lot of a conference of Army and Navy officers, which had several meetings in Paris to develop and improve existing radio communication procedure, and on which commission I had the honor to serve. Without much information on which to proceed, it is not surprising that the body of military men did not produce a completed project, but it did lay down certain principles upon which others more competent might build.

Roughly it was proposed to divide the principal countries needing and collecting international reports into several groups, and two classes of collective reports, known as *A* and *B,* were decided upon.

In the following table it was proposed that the letters *A, B, C, D, E* and *F,* indicate the grand groupings for which a collective report, *B,* is established. The numbers 1, 2, 3, etc., indicate the countries or groups of countries, for each of which a collective report *A* is drawn up:

Group A.

1. Great Britain.
2. Iceland, Denmark, Sweden, Norway.
3. Archangel, Esthinia, Finland.

Group B.

1. Holland, Belgium, France.
2. Spain, Portugal.
3. French North Africa.
4. Switzerland.

Group C.

1. Italy, Malta, Servia.
2. Egypt, Libya, Palestine.
3. Greece, Roumania, Constantinople.
4. Poland, Bohemia.

Group D.

1. Germany (or the German States).
2. Austria (or the Austrian States), Bulgaria.
3. European Russia.

Group E.

Africa (to be considered later).

GROUP F.

North America (to be considered later).

The countries charged with the preparation and the transmission of the collective reports *B* are the following:

Norway for Group A.
France for Group B.
Italy for Group C.
Germany for Group D.

The stations, the ranges of which are at least 3000 kilometres, which are to be utilized for the transmission of reports *B*, may be considered to be as follows:

Stavanger for Group A.
Lyons for Group B.
Rome for Group C.
Nauen for Group D.

The stations which will be utilized for the transmission of reports *A* will be determined later, after an agreement with the countries interested.

The reports *B* will be transmitted simultaneously three hours after the observations, *i.e.*, at the following hours: 0400, 1000, 1600, 2200.

As an illustration in Group *A*, Great Britain makes up a collective report *A*, and transmits it by radio to the high power radio station at Stavanger, Norway, and similarly the other countries numbered 2 and 3 in Group *A*. The Stavanger station then transmits, for international use, a collective report *B*.

It is noted that Group *E* is marked to be considered later, as well as Group *F*, North America.

With this information, various United States Government officials took up the subject for further development. This Committee concluded that the proposed scheme above outlined did not entirely meet the requirements for a world meteorological service, and in order to promote the realization of this highly desirable objective, recommended that each continent, adjacent waters and islands, be organized as a division as shown on the screen, that one country in each continental division be charged with the preparation of class *B* reports, and then transmission by high power radio station at designated fixed lines, to other continental divisions.

In accordance with this recommendation, the following continental divisions were suggested:

1. European
2. African.
3. Asiatic.
4. Oceanic.
5. North American.
6. South American.

The following organization for the transmission of Class *A* reports for the North American Division, was recommended:

GROUP A.

Canada, United States, Bermuda, Bahama Islands, Cuba, Mexico, and adjacent waters of the Atlantic, the Pacific and the Gulf of Mexico.

Reports from stations in Canada and the United States to be transmitted over telegraphic circuit to Washington, D. C., and San Francisco, Calif.

Reports from Mexico to be transmitted by radio and telegraph to San Francisco and Washington, D. C.

Reports from Cuba to be transmitted by radio and telegraph to Washington, D. C.

Reports from other insular stations and ships in this area to be transmitted by radio and telegraph via naval radio coast stations to Washington, D. C., and San Francisco, Calif.

GROUP B.

Alaska and Aleutian Islands, and adjacent waters.

Reports to be transmitted by radio and telegraph (via naval radio Cordova, Alaska) to San Francisco, Calif.

GROUP C.

Newfoundland and Northwest Atlantic.

Reports to be transmitted by radio and telegraph (via St. Johns) to Washington, D. C.

GROUP D.

West Indies (including South Coast of Cuba), Caribbean Sea, Central American, adjacent Pacific, and coastal stations of Colombia and Venezuela.

Reports to be transmitted by radio (via naval radio Cayey, P. R.) to Washington, D. C.

GROUP E.

Hawaiian Islands and adjacent waters.

Reports to be transmitted by radio (via naval radio Pearl Harbor) to San Francisco, Calif.

It is recommended that the United States be designated as the administration to prepare Class "B" reports for the North American Division and to transmit them via Annapolis and San Diego.

Each of these groups would prepare a collective *A* Group and transmit by appropriate radio stations or land wire stations to the next group, so that each group would have the benefit of the information from other groups in making their more or less local forecasts. Eventually all the Group *A* collective reports would reach Washington, where they would be used for general forecasting purposes, and would then be transmitted by the Annapolis high power radio station for international use, in the form of a collective *B* report. Similarly, one high power station in each of the other continental divisions would receive *A* reports from their proper division and transmit a collective *B* report which would be received in all the other countries.

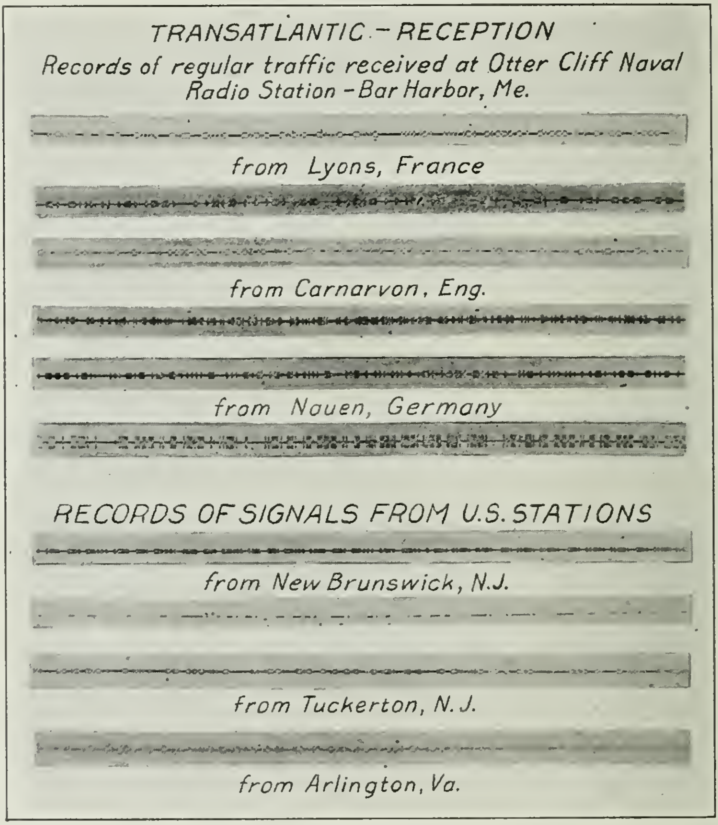
All of these collective *A* reports and collective *B* reports would be available at their collecting centres for local use, and transmitted to sea by local radio stations either on the coast or in the interior, for use of ships and aircraft.

The report of the American Committee is now being considered by the delegates to the Preliminary Conference on Communications, now meeting in Washington, and it is confidently hoped and expected that the above or a similar plan will be authorized and soon put into practice, when the whole world will have means by which better local and general forecasts of weather may be made, based on world-wide conditions.

Perhaps what I have to say now is not directly connected with the application of radio as applied to navigational problems, but indirectly finds some connection in case all available radio applications fail, and I have reference to another form of communication, which I wish to lightly touch upon, and that is the use of pigeons.

During the last ten months of the World War, U. S. Naval pigeons delivered 219 messages from seaplanes forced to land at sea. These planes were without any other means of communication, and credit must be given the pigeons for the saving of both men and machines. The most thrilling experience of any of our aviators is that credited to Ensign E. A. Stone, U.S.N.R.F., who, with Sub-Lieutenant Eric Moore of the Royal Naval Air Force, clung for eighty hours, without food or drink, to the underside of a seaplane pontoon. The duty of the above officers was convoying patrol, and after having met their ship coming from the westward, they sighted a periscope ahead and started in pursuit. They unfortunately lost their course in a slight fog, and at 11.30 A.M. were forced to land on the surface in a rough sea, their engine completely dead. Two pigeons were aboard, and these were

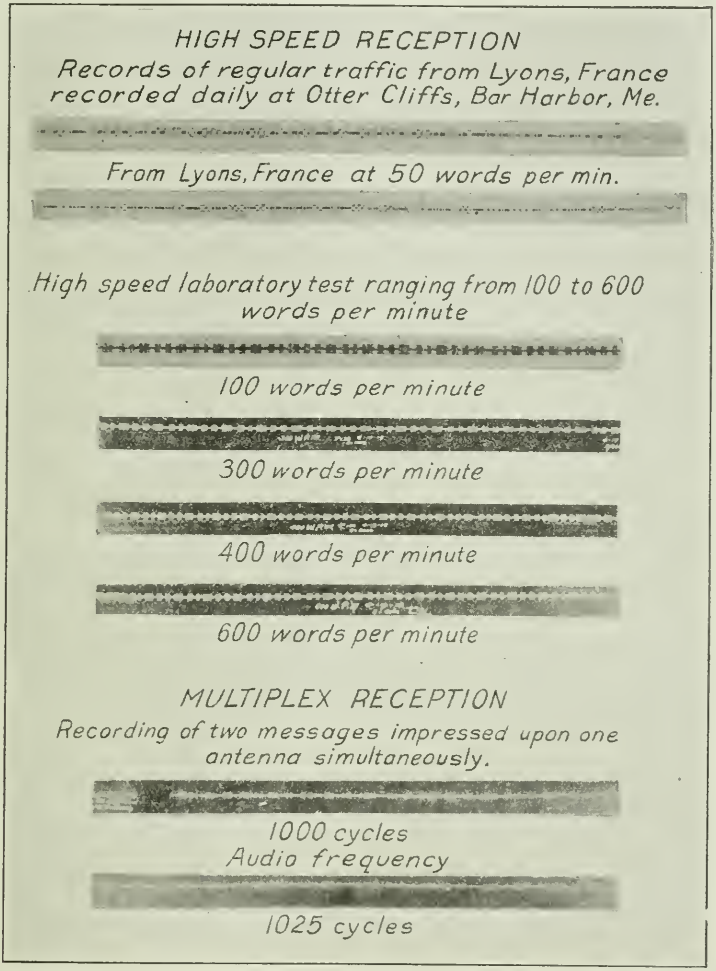
Part I.



Radio signals recorded by The General Electric Visual and Photographic Recorder, invented by Mr. C. A. Hoxie.

released at fifteen-minute intervals. The first pigeon arrived in Dunkirk with a message stating the whereabouts of the aviators and that their ship was sinking. Every available seaplane on the station was sent out in search; and although some of them flew as close as 800 feet from the wreckage and were easily discernible by the men on the water, eighty hours had elapsed before the aviators were rescued. Lieutenant Moore lost six of his toes from gangrene, finally dying in the hospital. Ensign Stone recovered, and until recently was stationed at the U. S. Naval Air Station, Anacostia, D. C. Many instances have occurred where pigeons operating on this side of the water have been instrumental in delivering messages requesting spare parts to be sent disabled

PART II.


HIGH SPEED RECEPTION
Records of regular traffic from Lyons, France recorded daily at Otter Cliffs, Bar Harbor, Me.
From Lyons, France at 50 words per min.
High speed laboratory test ranging from 100 to 600 words per minute
100 words per minute
300 words per minute
400 words per minute
600 words per minute
MULTIPLEX RECEPTION
Recording of two messages impressed upon one antenna simultaneously.
1000 cycles
Audio frequency
1025 cycles

Radio signals recorded by The General Electric Visual and Photographic Recorder, invented by Mr. C. A. Hoxie.

planes, and one pigeon at Cape May is credited with the rescue of one of our pilots off the Jersey coast last winter.

For those who may be interested in the modern development of the radio art, the accompanying diagrams of recorded signals show high-speed signaling by radio, recorded photographically. These show a transmission and reception of 600 words per minute in laboratory tests, and it is fully expected that some such figure may be approached in modern everyday practice.

Reagent for Cobalt.—A new reagent for the detection of cobalt is described by H. S. van Klooster (*Journ. Am. Chem. Soc.*, 1921, xliii, 746–749). Nitroso R-salt, the nitroso derivative of 2, 3, 6 beta naphthol disulphonate, yields a red color with cobalt salts in aqueous solution. Silver, lead, cadmium, and other metals which have colorless ions do not interfere with the reaction. Salts of iron, nickel, chromium, and copper also give colors with the reagent, but these colors are destroyed by nitric acid, while the color due to the presence of cobalt is not destroyed. In order to test for cobalt, an aqueous solution is prepared containing from 1.5 to 2.0 grams of anhydrous metallic salts in each 100 c.c. To 2 c.c. of this solution are added 1 gram of powdered sodium acetate and 2 c.c. of a one-half per cent. aqueous solution of the nitroso R-salt. The resulting solution is heated to boiling over a small flame; 1 c.c. of concentrated nitric acid of specific gravity 1.4 is gradually added; and boiling is continued at least one minute. If as small an amount of cobalt as 0.03 millegram be present in each cubic centimetre of the solution of metallic salts, its presence will be shown by the development of a red color.

J. S. H.

The National Fertilizer Association will hold its 28th annual convention at White Sulphur Springs, W. Va., beginning June 20, 1921.

The program will include addresses and discussions on subjects that are of vital interest to the fertilizer manufacturer, in view of present business conditions. These subjects will include costs and cost of accounting systems, chemical and manufacturing problems, sales methods, labor and transportation problems, etc.

The Southern Fertilizer Association, the Soil Improvement Committee of the National Fertilizer Association and the Soil Improvement Committee of the Southern Fertilizer Association will hold meetings during the time of the Convention.

LEONARDO DA VINCI—NATURAL PHILOSOPHER AND ENGINEER.*

BY

JOHN W. LIEB, M.E.

Vice President, the New York Edison Company. Member of the Institute.

THE epoch of human progress in which Leonardo da Vinci lived encompasses the latter half of the fifteenth and the first half of the sixteenth century, known as the period of the Italian Renaissance.

This is the period known in history as the Revival of Learning with its new conceptions of philosophy and religion; its dedication to new types in the arts; its casting aside of astrology, alchemy and the black arts for the natural sciences; its manifold inventions and discoveries; and its changed political systems.

In a broad sense the Renaissance signified a rescue from oblivion of the classical works of Greece and Rome in their influence on science, literature and the arts, a return to nature and the realities of life, and the evolution of mankind toward individual liberty as a reaction against medieval feudalism and asceticism.

While the Renaissance typified a return to nature and the restoring of classical models, it also represented a distinct progression beyond, as indicated by Prof. J. H. Robinson in his essay " The Mind in the Making ":

> " Greek civilization was founded on slavery and a fixed condition of the industrial arts. The Philosopher and scholar was estopped from fumbling with those every-day processes that were associated with the mean life of the slave and servant. Consequently there was no one to devise the practical apparatus by which alone profound and ever-increasing knowledge of natural operations was possible. The mechanical inventiveness of the Greeks was slight, and hence they never came upon the lens; they had no microscope to reveal the minute, no telescope to attract the remote; they never devised a mechanical timepiece, a thermometer or a barometer, to say nothing of cameras and spectroscopes. Archimedes, it is reported, disdained to make any record of his ingenious devices, for they were unworthy the noble profession of a Philosopher."

In this period of awakening and release from the tyranny of precedence and authority we find that many of the courts of

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* Presented at the Annual Meeting of the Institute held Wednesday, January 19, 1921.

Europe, Imperial, Regal and Ducal with the consolidation of territories and the increase in wealth began to show outward splendor and luxury, their rulers becoming liberal patrons of the arts, and they attracted to their festivities and tournaments the flower of chivalry and the popular idols in art, music, and poetry.

LEONARDO DA VINCI
Portrait. Gallery Uffizi, Florence.

Under the powerful protection and patronage of the illustrious Houses of Medici and the Sforza, art in its various manifestations attained a brilliancy and appreciation which made artists and poets most sought after in all the Ducal Courts, and we have ample testimony of its popular appreciation in the enthusiastic and laudatory testimony of contemporary prose and poetry.

It was in Italy that the glories of the Renaissance had their typical manifestation, and the splendor of the Ducal Courts, aided by the wealth of Italian Patricians and merchant princes, attracted to her all the learning of the times. The Universities of Bologna, Padua and Salerno were famous during the middle ages for the study of law, physics and medicine, and during the fifteenth and sixteenth centuries the first two still enjoyed world-wide fame. The Medieval curriculum, however, offered no definite place for the new knowledge developed by the revival of learning, the search after truth, and the unveiling of the secrets of nature, which had no recognized chairs for their exposition.

In the early Renaissance, chairs in the universities were founded under the title of Rhetoric and learned men expounded orally, to students from every nation in Europe, their accumulated knowledge of antiquity, a confused mass of Greek, Roman and Arabic erudition, including under this subject history and metaphysics, law and science, civic institutions and the art of war, poetry and oratory, religious ritual and Philology—all going to form the heterogeneous subject matter classed under the scholastic term " Rhetoric."

It was in the very midst of this interesting period that Leonardo da Vinci was born in 1452 in the village of Vinci near Florence, Italy, as the natural son of Piero da Vinci, a notary or councillor of the seignory of Florence, and Caterina, a woman of the peasant class.

The year of his birth Leonardo's father married a young woman of his own social level, and his mother married a peasant farmer and we lose all further track of her. Leonardo's father married three times and had eleven children, Leonardo having reached the age of twenty on the birth of the first legitimate child.

As a young man Leonardo became interested in music and according to Vasari, the gossipy biographer of that time, " He played on the lyre, singing and improvising devinely." He became interested in making sketches and plaster reliefs, and when his father showed some of these drawings to the great Florentine Master Verrochio, he was accepted as an apprentice in that master's art shop or "bottega."

His master, like most of the Renaissance Craftsmen, was a gold and silver smith and a moulder in bronze as well as a sculptor and painter, so that his pupils acquired knowledge and practice in every branch of pictoral and plastic art. In addition Leonardo became interested in mathematics, mechanics and the making of experiments. As a mere youth he had acquired a life-long habit of jotting down, in rough sketches, scrawls and hasty notes, what he saw, always carrying a note-book with him. These later notes bear dates beginning with his thirty-seventh year, and he continued to compile data and material for his manuscripts without serious interruption during the succeeding thirty years.

The Lord's Supper. Present condition. S. Maria della Grazia, Milan.

He left Florence about 1480 and is believed to have travelled throughout Italy during the next few years. About 1484 he was invited by Duke Ludovico il Moro to come to Milan, and for the next fifteen years was attached to the Ducal Court and took a conspicuous part in its activities, acting as Director of Pageantry in planning and organizing court festivities, making improvements in the Ducal Castles and estates, constructing canal and irrigation works in Lombardy and executing important work as painter and sculptor. On the fall of the Ducal House of the Sforza, Leonardo left Milan, spending some time in Venice, then entering the service of Cesare Borgia as Military Engineer, and later returning to Florence where much of his work in art was done.

In 1508 he returned to Milan and in the following years he spent much of his time in investigation, experiment and research, delving into almost every realm of nature, planning all kinds of mechanism and machinery and investigating the laws of operation of natural and physical phenomena.

In 1515 he accompanied Francis the First to France as Court Painter and died in 1519 at the age of sixty-nine, at the Manor House of Cloux, Amboise, which the King had assigned to him as a residence. His was a most engaging personality, a brilliant conversationalist, musician and extemporizer, a fine presence and noble bearing, physically strong and of athletic build. He was every inch a courtier and possessed many of the graces required of a court favorite.

Such is a brief summary of Leonardo's life.

At the outset it should be stated, frankly, that it is quite impossible within the time that can be accorded to one address to give more than a mere outline of the life work of this extraordinary genius, even though we endeavor to confine our consideration to his activities in the realms of philosophy and engineering.

THE MANUSCRIPTS.

Any study of Leonardo must necessarily concern itself primarily with a consideration of his manuscripts, for it is through these rather than through any contemporary chronicle or products of his genius that he reveals himself to us.

Just how many manuscript volumes he left to posterity is not accurately known, and their arrangement and grouping into subject matter is in inextricable confusion. We know that altogether over 5300 sheets of his note-books have been found, covered with notes and sketches on one or both sides, the sheets varying in size from 4″ to 12″ long and from 3″ to 9″ wide.

In his will he left all of his books, sketches and paintings to Francesco Melzi, his pupil and friend, who removed them to the family seat at Vaprio near Milan, where they were carefully preserved for a time, but on Melzi's death in 1570 became widely scattered.

Three volumes including 1222 sheets have been brought together into one volume known as the Codice Atlantico, now in the Ambrosian Library, Milan. Twelve other volumes, comprising some 2200 sheets, are now in the library of the Institute de France, Paris; 596 sheets are in the Forster Library, S. Kensington Museum, London; 566 sheets in the Royal Library, Windsor Castle; 566 sheets in the British Museum, London, and the rest distributed, some at Holkham Hall and at Milan, Rome, Turin, Florence, Venice, etc.

Sketches for equestrian monuments.

The notes, with comparatively few exceptions, are written backhand, in oriental style, *i.e.*, from right to left, " mirror-writing," in an archaic style of Italian with a tendency to group the letters phonetically. Some of the sentences are chopped off in the middle and translation is further complicated by the use of archaic phrases, colloquialisms, abbreviations, absence of punctuation, etc.

The writing is executed in somewhat Byzantine characters and, to the expert, the reading can best be accomplished with the aid of a mirror.

We find on the very same sheet of these notes, in utter confusion of arrangement, an architectural plan, a sketch of a human figure or face—often a grotesque, a sketch of a leaf, plant or flower, a study of a geometric figure or drawing, or a machine, a calculation of cost or power required, all intermingled on the same page and having no relation whatever to one another.

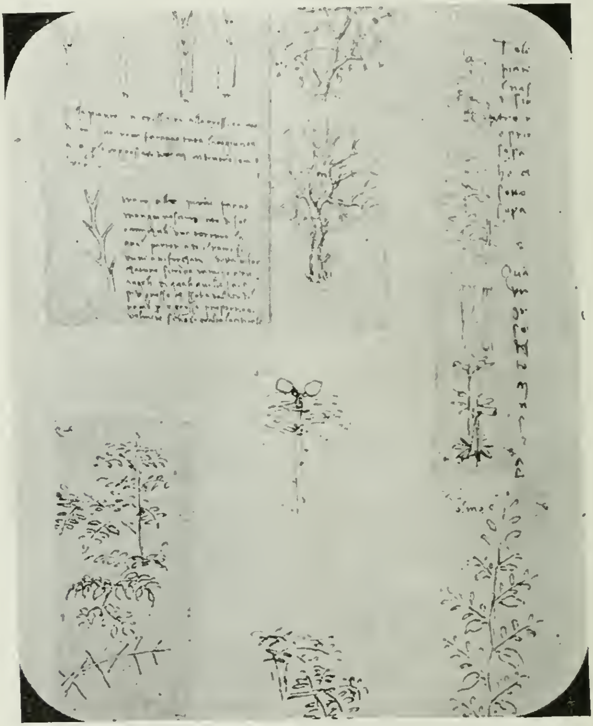
Nearly all of the manuscripts have now been reproduced in facsimile with literal reproductions of the text, with transcriptions into modern Italian and usually also with a translation into French, English or German. The Codice Atlantico is available in a very satisfactory Italian edition, the manuscripts in the Windsor Library treating of anatomical subjects are reproduced in a recent excellent Norwegian edition, and the other notes have appeared in more or less satisfactory editions due to the use of primitive photo-lithographic processes. No complete edition, however, exists of the manuscripts in the Windsor Library, and students are awaiting with much interest the promised bringing together in one edition of all of Leonardo's manuscripts in a "Corpus Vincianum," which will supply to students considerable material hitherto unpublished.

Several series of related notes, distributed throughout the manuscripts, have been brought together, arranging them as it is believed was intended in the form of treatises. These comprise a most complete and remarkable text-book called "The Treatise on Painting," which has had numerous editions in several languages, a treatise "On the Motion and Measurement of Water," and a booklet on the "Flight of Birds."

It appears to have been Leonardo's intention to compile a number of treatises which should embody the results of his investigations, for he says:

> "This will be a collection without order made up of many sheets which I have copied here, hoping afterwards to arrange them in order in their proper places according to the subjects of which they treat." Ms BM 263 Ar (Windsor)

In addition to the treatises mentioned above, he speaks of writing a book "About the Human Figure"; in another place he refers to a book on "Light and Shade," and in another on "Movement and Weight," and Lomazzo refers to a treatise by Leonardo on the anatomy of the horse. One of the few contemporary references to these manuscripts occurs in the diary of Antonio de Biatis, secretary to the Cardinal of Aragon, who visited Leonardo at Amboise in 1517. He says:



Botanical sketches. Arrangement of leaves and limbs of trees.

> "This gentleman (Leonardo) has written of anatomy with such a wealth of detail, illustrating by his art both limbs and muscles, nerves, veins and ligaments of the inward parts, and of all that may be demonstrated in the bodies of men and of women, in a way that has never before been equalled by any one else; we have seen with our own eyes, and he has also told us that he has dissected more than thirty bodies of men and women of all different ages. He has also treated of the nature of water, of various machines and of other matters which he has dealt with in an endless number of volumes; and all in the common tongue, which when they are made public, will be profitable and very delectable."

Leonardo was a keen searcher after the cause and reasons for the things he saw about him, and his greatest delight was in discovering the fundamental laws underlying natural and physical phenomena.

He was continuously endeavoring to express the facts and manifestations of nature in terms of what he called a " regola "—a general rule or law. His notes are full of such expressions as these: Try this; observe that; note the effects of this; go tomorrow and ask Maestro Antonio how mortars are placed on bastions by day or by night. He says: " I remind you that you confirm your statements and your conclusions through examples and not assertions, which would be too easy. You should say: Proven by experiment! " Here we have revealed an indomitable spirit whose restless energy and depth of thought, whose desire to know how and why and insatiable yearning to understand nature in all her wonderful manifestations is unique in the history of mankind, for there is hardly a department of human knowledge which he has not touched upon and to which his notes do not make some pertinent reference.

Several questions arise which we should endeavor to answer at this time.

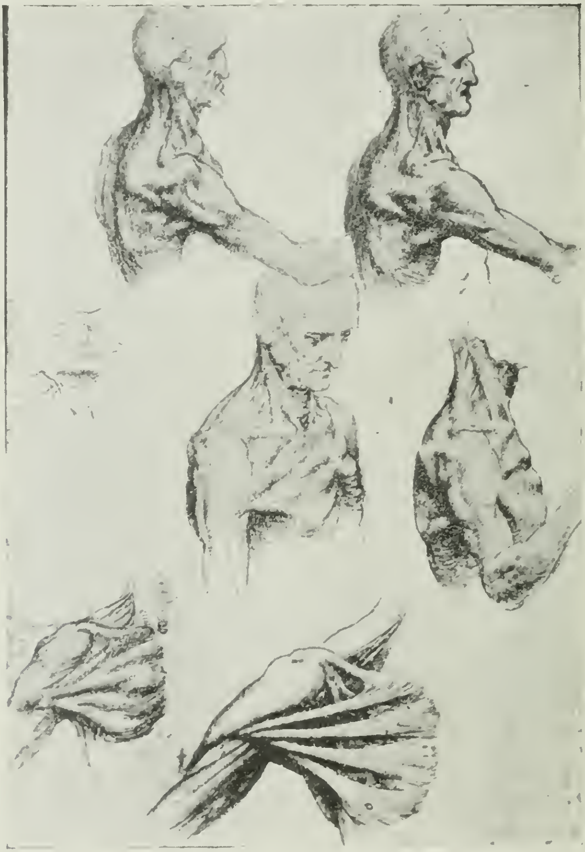
Why did Leonardo usually write from right to left, " mirror-writing," as it is called?

Volumes have been written by students of Vinciana offering many varied explanations for this mirror-writing of Leonardo, but Prof. Arthur L. Beeley in a recent monograph entitled " An Experimental Study of Left-handedness " has shown conclusively in his exhaustive investigation, covering a school population of over 100,000 pupils, that there is one " mirror-writer " in every group of about 2500 children of elementary school age, and he concludes from his careful study of left-handed children that " mirror-writing " is by far the easier style of writing for all sinistrals, and Leonardo was most certainly left-handed.

Another question arises, as to the literary attainments of Leonardo, and as to his familiarity with classical and contemporary authors and writers on natural science and philosophy.

In one of his notes in the Codice Atlantico, Ms C A Fol 119r, he says:

" I am fully aware that the fact of my not being a man of letters may cause certain arrogant persons to think that they may with reason censure me, alleging that I am a man ignorant of book learning. Foolish talk! Do they not know that I might retort by saying, as did Marius, to the Roman Patricians: 'They who themselves go about adorned in the labor of others will not permit me my own.' They will say that because of my lack of book learning I cannot properly express what I desire to treat of. Do they not know that my subjects require for their exposition experience rather than the words of others? And since experience has been the mistress of whoever has written well, I take her as my mistress, and to her in all points make my appeal."



Muscles of the chest and neck.

And in this interesting note in which he appears as the original chastiser of the "nature fakir":

"I know well that because I am illiterate certain presumptuous ones seem to think it proper to criticise me by alleging that I am without literary knowledge.

Good writing is based on good knowledge of nature; and as greater consideration should be given to cause than effect, so I would give greater praise to a good naturalist without literary knowledge, than to a good literary man without knowledge of nature." Ms CA Fol 76r

But, was Leonardo illiterate? Not at all! and we should answer this question now before we come to consider his work as a philosopher. We find him to have been familiar with many classical and contemporary authors, although, as Richter says of him:

> "It was evidently no part of his ambition to be deeply read, and he more than once expressly states that he did not recognize the authority of the Ancients on scientific questions, which in his day was held paramount. Archimedes is the sole exception, and Leonardo frankly owns his admiration for the illustrious Greek to whose genius his own was so much akin."

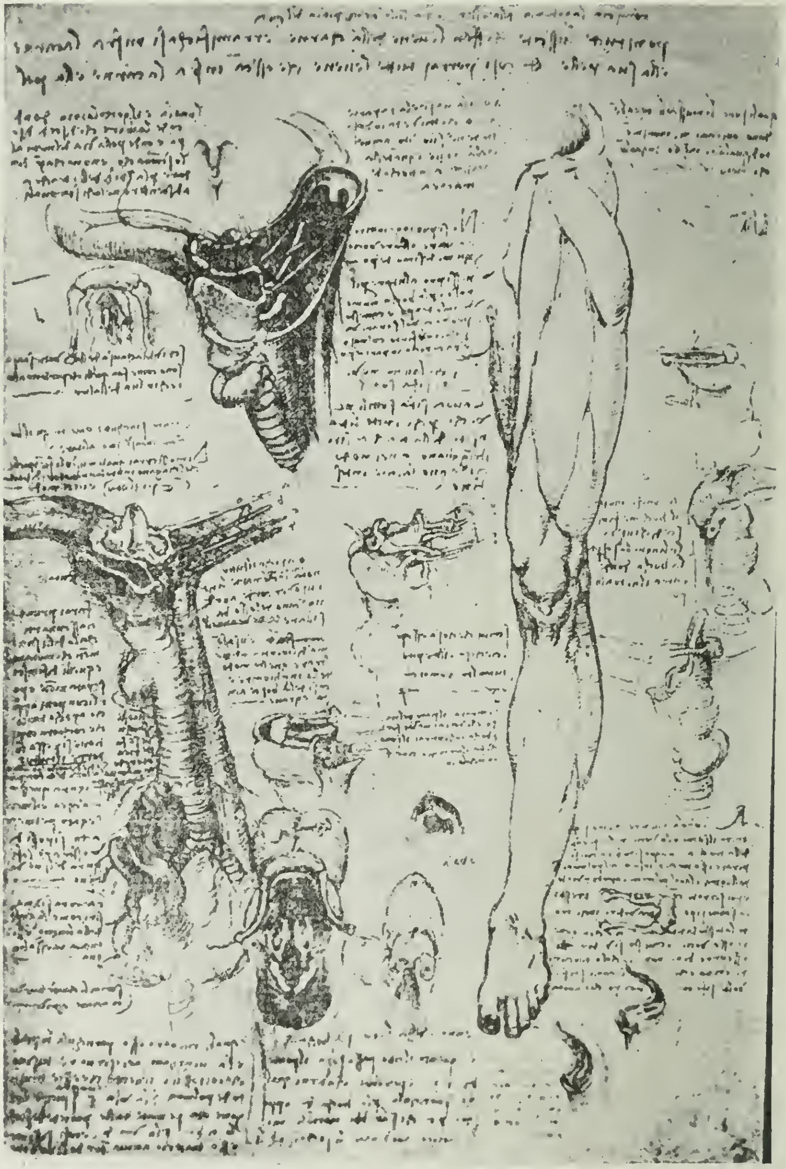
Nevertheless, he frequently quotes from Aristotle, Anaxagoras, Pliny, Hippocrates, Vitruvius, Avicenna, etc.

Throughout his notes we find references to books which he wishes to consult or obtain and where they may be found, as, for instance: "Take the book by Vitolone, on the measurements of the public buildings"; "an algebra which the Mariani have, written by their father"; "get Messer Fazio to show you the book on proportion"; "the measurement of the sun, promised me by Maestro Giovanni, the Frenchman"; "get the Friar of Brera to show you the book 'De Ponderibus'"; "The Archimedes belonging to the Bishop of Padua"; "On the increase of the Nile, a small book by Aristotle"; "the heirs of Maestro Giovanni Ghiringallo have the works of Pelacano," etc.

Before leaving the manuscripts, while we are not here concerned with his purely literary activities, we should refer to several of the interesting letters they contain, as they throw considerable light on his personality and his intensely human sympathies.

In a letter written about 1480 to Duke Ludovico Il Moro offering his services as Military Engineer, he says:

> "Having, My Most Illustrious Lord, seen and now sufficiently considered the proofs of those who consider themselves masters and designers of instruments of war, and that the design and operation of said instruments is not different from those in common use, I will endeavor without injury to anyone to make myself understood by your Excellency, making known my own secrets, and offering thereafter at your pleasure, and at the proper time, to put into effect all those things which for brevity are in part noted below—and many more, according to the exigencies of the different cases.



Anatomy of the throat, muscles of the leg, etc.

I can construct bridges very light and strong, and capable of easy transportation, and with them pursue or on occasion flee from the enemy, and still others safe and capable of resisting fire and attack, and easy and convenient to place and remove; and methods of burning and destroying those of the enemy.

I know how, in a place under siege, to remove the water from the moats and make infinite bridges, trellis work, ladders and other instruments suitable to the said purposes.

Also, if on account of the height of the ditches, or of the strength of the position and the situation, it is impossible in the siege to make use of bombardment, I have means of destroying every fortress or other fortification if it is not built on stone.

I have also means of making cannon easy and convenient to carry, and with them throw out stones similar to a tempest; and with the smoke from them cause great fear to the enemy, to his grave damage and confusion.

And if it should happen at sea, I have the means of constructing many instruments capable of offense and defense, and vessels which will offer resistance to the attack of the largest cannon, powder and fumes.

Also, I have means by tunnels and secret and tortuous passages, made without any noise, to reach a certain and designated point; even if it is necessary to pass under ditches or some river.

Also, I will make covered wagons, secure and indestructible, which entering with their artillery among the enemy will break up the largest body of armed men. And behind these can follow infantry unharmed and without any opposition.

Also, if the necessity occurs, I will make cannon, mortars and field-pieces of beautiful and useful shapes, different from those in common use.

Where cannon cannot be used, I will contrive mangonels, dart throwers and machines for throwing fire, and other instruments of admirable efficiency and not in common use; and in short, according as the case may be, I will contrive various and infinite apparatus for offense and defense.

In times of peace I believe that I can give satisfaction equal to any other in architecture, in designing public and private edifices, and in conducting water from one place to another.

Also, I can undertake sculpture in marble, in bronze or in terra cotta; similarly in painting, that which it is possible to do I can do as well as any other, whoever it may be.

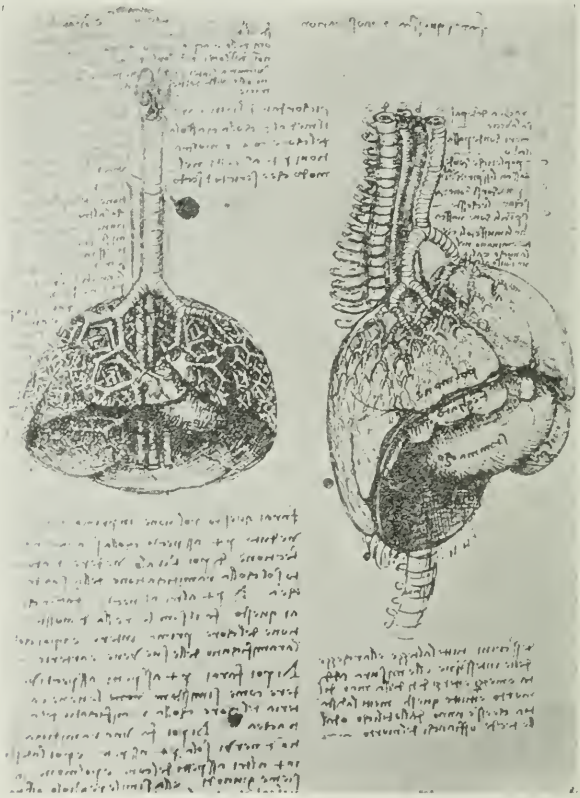
Furthermore, it will be possible to start work on the bronze horse, which will be to the immortal glory and eternal honor of the happy memory of your father, My Lord, and of the illustrious House of Sforza.

And if to anyone the above mentioned things seem impossible or impracticable, I offer myself in readiness to make a trial of them in your park or in such place as may please your Excellency; to whom, as humbly as I possibly can, I commend myself." Ms CA Fol 391r

A most self-laudatory letter, it is true, but Leonardo seems to have demonstrated his ability to produce results in all these matters.

At Pavia, August 18, 1502, where Cesare Borgia had gone to render homage to Louis XII, is dated a letter-commission from the former, conferring on Leonardo—his private architect and engineer, the commission of Inspector General of the Duchy of Urbino:

"To all our Lieutenants, Castellans, Captains and Condottieri, officers and subjects, who receive this notice, it is commanded and ordered, in favor of our very excellent and favorite private architect and Engineer General Leonardo Vinci, bearer of these letters present, whom we have charged to visit the places and the fortresses of our estates, in order to have them put back into condition according to the exigencies and in his own decision, to guarantee him freedom of movement, all exemption from payment of public taxes; to give a friendly welcome to him and his companies; to help him in visiting, measuring and estimating the localities as much as he pleases; and to this end to place at his disposal the men he requires; to give him all aid and assistance that he requires and finally carry out our wish, that for the work to be done in our domains all engineers shall confer with him and conform to his orders." Original in archives of Duke Melzi, Milan.



Lungs and thorax.

We should not leave further consideration of the manuscripts without referring to the prophesies, fables, beastiaries, and rebuses in which the notes abound.

A few aphorisms may be quoted:

"Ask counsel of him who governs himself well" Ms Hiii Fol 118v

"When fortune comes seize her with a firm hand and in front, I counsel you, for behind she is bald" Ms C A Fol 289v

"As a day well spent gives cheerful sleep, so a life well spent gives cheerful death" Ms Tr Fol 27r

"Nature never breaks her own law" Ms E Fol 43v

"To devise is the work of the Master, to execute the act of the servant" Ms CA 109va

"In speculation about perpetual motion, how many vain chimeras have you created in that quest? Go and take your place with the seekers after gold (Alchemists)" Ms SKM ii_2 Fol 67r

"Although human ingenuity makes a variety of inventions answering by different means to the same end, it will never devise an invention more beautiful, more simple or more direct than does nature because in her inventions nothing is lacking and nothing is superfluous" Ms WAN iv Fol 184r

"Science is the captain, practice the soldiers" Ms J Fol 130r

"Avoid studies of which the result dies with the maker" Ms SKM iii 36b

"Practice should always be founded on sound theory" Ms G Fol 8r

"As is the mould, so will be the casting." R 21_7 H_2 52b and Ms H Fol 100 [43r] v

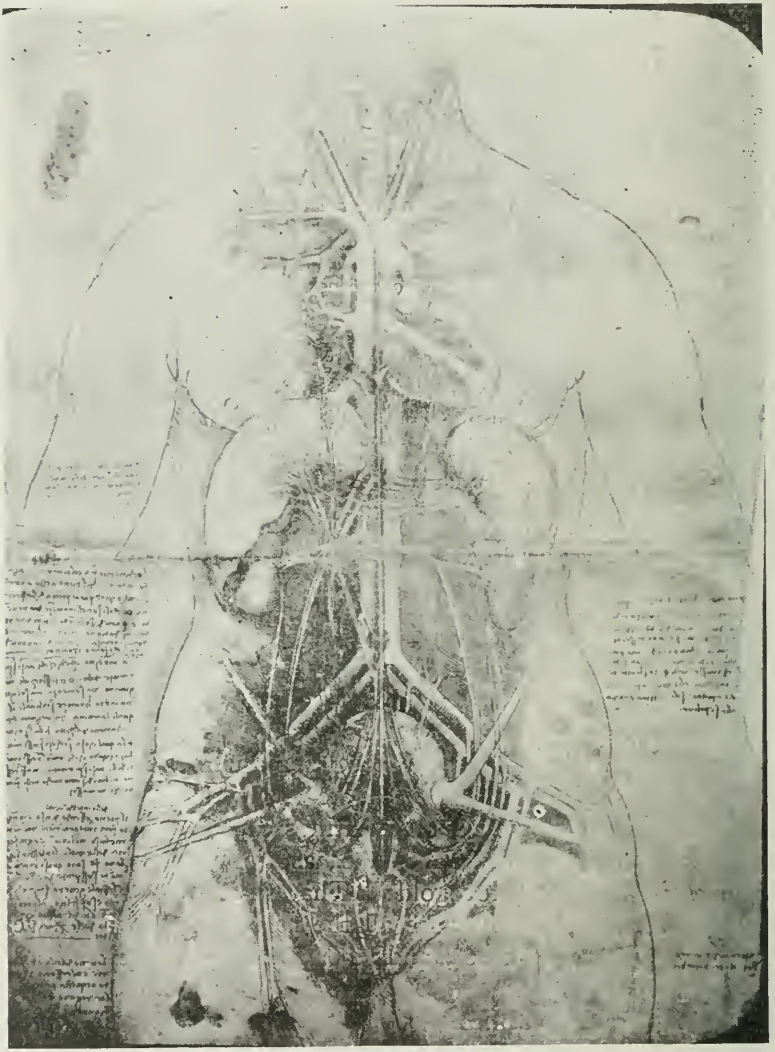
His fables cover such subjects as: "The Flame and the Candle," "The Elm and the Fig Tree," "The Walnut Tree and the Tower," etc.

The allegories refer to such subjects as: Cruelty, Prudence, Justice, Ingratitude, etc., and among beastiaries: The Dolphin, The Serpent, The Dragon, The Bat, etc.

There are also some curious writings called prophesies about the earth, about animals, plants, etc., as, for instance, referring evidently to the quest for gold: "That shall come forth from hollow caves which shall cause all the natives to toil and sweat with great agitation, anxiety and labor, in order to gain its aid." Ms C A Fol 37v

Having briefly outlined in the foregoing the environment of Leonardo and the many sided quality of his genius, we are now prepared to examine his manuscripts and notes in some detail with special reference to his researches, thoughts and activities as a Natural Philosopher and Engineer.

In order to attempt to do a measure of justice to these phases of the general subject, it becomes necessary for us to dismiss, in just a few words, consideration of those accomplishments for



Viscera of human body.

which he has won immortal fame as among the world's greatest artists long before his unique achievements in science and engineering had become generally known and appreciated.

PAINTING AND SCULPTURE.

We have already referred to that remarkable production which forms the basis of his applied art, the Treatise on Painting, which is a complete text-book in itself, so modern in its conception and useful in its suggestions that a modern translation is being used to-day as a text-book in French art schools.

Although evidently a mosaic and compilation from his notes, probably brought together for use in teaching in the Accademia Vinciana which he founded in Milan, it is of itself a monument to his genius as an artist and scientific investigator. In it he sums up tritely and profoundly the painter's purpose: "A good painter has two chief objects, to paint man and the intention of his soul. The former is easy, the latter hard, because he has to represent it by the attitudes and movements of the limbs."

A glance at the sub-heads into which the book is divided will show the breadth of the treatment:

1. The nature of paintings, poetry, music and sculpture.
2. Precepts for the painter.
3. Of positions and movements of the human figure.
4. Of drapery.
5. Light, shade and perspective.
6. Of trees and foliage.
7. Of clouds.
8. Of the horizon.

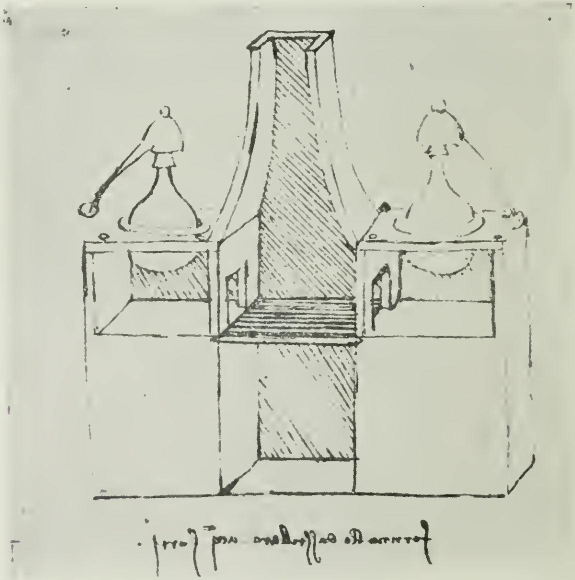
How completely modern is the treatment will appear strikingly from a few quotations:

"These rules (for painters) secure to you a sound and liberal judgment; because good judgment is born of good understanding, and good understanding is the result of reasoning based on good rules and good rules are children of good experience, the common mother of all sciences and. arts. Solmi, Frammenti Letterari e Filosofici, p. 79.

"The first picture consisted merely in a line which surrounded the shadow cast by the sun upon a wall" Ms ASH I 18a, and again,

"The eye which is the window of the soul, is the chief means whereby the understanding may most fully and abundantly appreciate the infinite works of nature; and the ear is the second; inasmuch as it acquires its importance from the fact that it hears the things which the eye has seen. * * * If you call painting "Dumb Poetry" then the painter may say of the poet that his art is "Blind Painting." * * * Although the poet has as wide a choice of subjects as the painter, his creations fail to afford as much satisfaction to mankind as paintings, for while poetry attempts with words to represent forms, actions and scenes, the painter employs the exact images of the forms in order to reproduce these forms. Consider, then which is more fundamental to man, the name of the man or his image? The name changes with change of country; the form is unchanged except in death' Ms Ash I Fol 19r, and (continuing in a most interesting discussion as to the relative merits of sculpture and painting too extended to reproduce here) he adds: 'As practising myself the art of Sculpture no less than that of painting and doing both the one and the other in the same degree, it seems to me that without suspicion of unfairness I may venture to give an opinion as to which of the two is the more intellectual and of the greater difficulty and perfection' Ms Ash I Fol 25r, and again: 'The comparison of poetry, painting, and sculpture resolves itself into a consideration of the relative importance of the senses to which these manifestations of art make their appeal."

Leonardo's greatest work of art and one of the world's greatest paintings, "The Lord's Supper," needs no description here. A critic has said of it: "It has a gallery of its own in the way of copies; a library of its own in the form of description; an epic of its own in the annals of maltreatment." His next most important work of art is the famous portrait of "Mona Lisa," and others more or less well known whose authenticity is unquestioned are the "Virgin of the Rocks," "Saint Anne," "The Holy Family," "The Adoration of the Magi," "S. Hieronimus," etc. A severe critic of Leonardo has said: "His fame as a painter rests upon



Furnace for acids.

four or five unfinished or half ruined paintings;" and again: "His writings and the thoughts buried in them were not known to his contemporaries nor yet, with the exception of a few fragments, to those who came after him. It was reserved for the nineteenth century to see them published." Vasari, the contemporary biographer, says: "It will be seen how Leonardo, by virtue of his genius as an artist, began many things but never completed anything, as it seemed to him that his hand could not attain to the artistic perfection in his works at which he aimed, because in his mind he formed and created such marvellous difficulties that they could never be expressed by the aid of hands, no matter how excellent the capability of which they were possessed."

Of Leonardo's work as a sculptor there is little or nothing left to the world that is authentic, although we have a number of references to his works, notably the model for the great equestrian statue of Duke Franceso Sforza. Jovinus, a contemporary historian, in the few lines he devotes to Leonardo mentions him as a painter, but accords great praise to his sculpture which he says Leonardo preferred to painting. We must also omit consideration of his interest in music and pageantry to which his notes contain numerous references, not only in the text but in sketches of various types of musical instruments designed by him, and costumes, decorations, and devices for court festivities and tournaments in which he coöperated.

PHILOSOPHY.

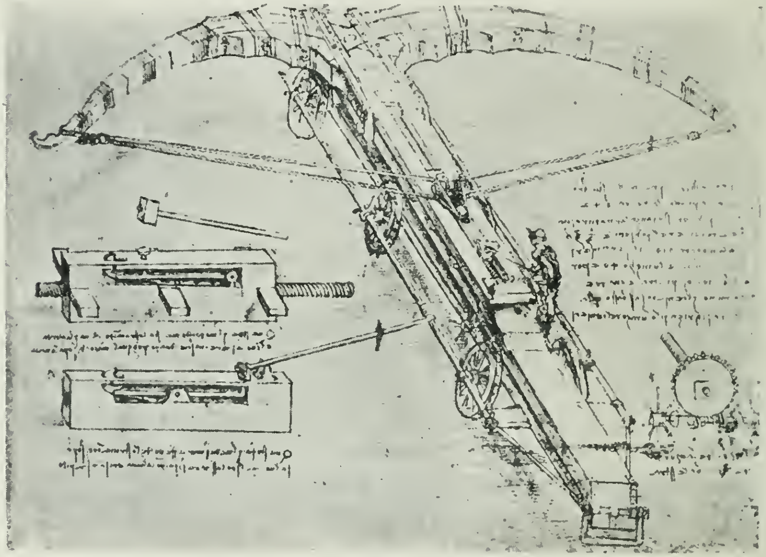
Leonardo's philosophical writings extend over the whole realm of speculative and natural philosophy, although he had a contempt for metaphysics; and in matters of ethics as well as science he reached his conclusions by a process of observation and experimentation, and drawing deductions therefrom rather than by recognizing the dictum of revelation of an external superior authority.

In matters of religion he seems to have been to a considerable extent an agnostic, but his doubts and weak faith and beliefs did not lead him into the kind of "pernicious activity" which led Galileo, Savonarola, Giordano Bruno and others into serious conflicts with the established church.

He seems to have escaped placing himself in the attitude of open hostility to the tenets of the church, and while he has given expression by the sarcasm of pen and pencil to his opinion of priests and monks, it is known that he died reconciled to the church.

It is difficult, from the mass of available material, to give an adequate conception of his philosophy which in many respects was not always consistent and was subject to change, as appears from a number of contradictions contained in his notes in which his opinions became modified or changed.

A few quotations which reflect the contemplative side of our subject in language which is often lofty and poetic, although thoroughly modern in its fundamental concepts, may be of interest:



Catapult for throwing heavy darts and arrows.

"O wonderful necessity! Thou with mighty reason obliges all effects to follow for their causes and with mighty and irrevocable laws forces every natural action with a brief operation to obey you. O Mighty Action! What ingenuity could penetrate such nature—what tongue could explain such marvels. This directs human discourse toward divine contemplation." Ms CA 345vb

"And Thou, O Man, who by these my labors doest look upon the marvelous works of nature, if thou judgest it to be an atrocious act to destroy the same, reflect that it is an infinitely atrocious act to take away the life of man. For thou shouldst be mindful that though what is thus compounded seem to thee of marvelous subtlety, it is as nothing compared with soul that dwells within this structure, and in truth, whatever this may be, it is a divine thing which suffers it thus to dwell within its handiwork at its good pleasure, and wills not that thy rage or malice should destroy such a life, since in truth he who values it not does not deserve it." Ms WA Fol A2r

" There will be many who will abandon work and labor and poverty of life and possessions and will go to dwell among riches and in splendid buildings, pretending that this is a means of becoming acceptable unto God." McCurdy, L.d.V. Note Books, p. 276.

" Aristotle says in the third chapter of his ethics: Man is worthy of promise or of blame only in these things which are in his power to do or not to do." Ms CA 284b; 865b

" Nature is so delightful, so abundant in her variety that among trees of the same variety one does not find one tree which resembles another and not only the trunk, but the branches, the leaves and the fruit—not one of these can be found the same as another." Solmi, Frammenti Letterari e Filosofici, p. 12.

" Every act of nature is accomplished by her in the quickest possible time and most direct manner." Ms G Fol 75r

" Our life is made by the death of others." Ms H_2 41b

" Every action is exerted through motion." Ms CA Fol 83v

" Motion is the cause of all life." Ms Tr Fol 36r

" Before deducing a general rule from the specific case, try the experiment two or three times and observe if the experiments always give the same results." Ms A Fol 47r

"Science is that product of the mind which has its origin in fundamental principles beyond which you cannot go; as in the science of Geometry, which, beginning with the surfaces of bodies, has its origin in lines the delimitations of these surfaces. But with this we are not content, because we know that the line has its origin in the point, and again beyond this we cannot go, etc."

Solmi—Frammenti Letterari e Filosofici, page 77.

(And this word of warning to future generations of engineers:)

" Effect of my rules: If you ever asked me what these rules accomplish or of what good they are, I should answer that they keep a restraining hand on Engineers and Investigators—teaching them not to promise themselves or to others impossible things and in consequence may be considered either crazy or imposters."

ASTRONOMY.

Leonardo's researches on astronomy and geology have, throughout, the stamp of independent thought and mature reflection based on his observations and investigations.

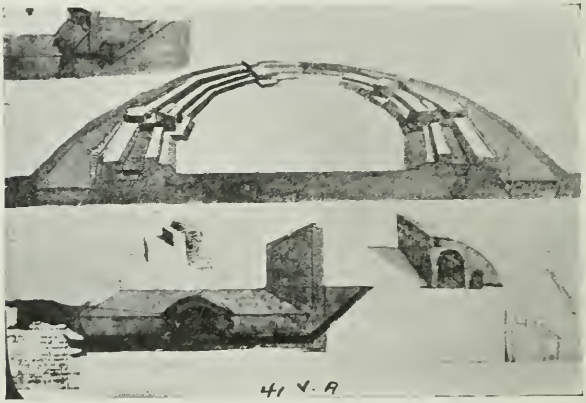
He quotes the ancients only insofar as is necessary to refute their arguments which he often presents and confutes in the old form of question and answer.

The spherical form of the earth he takes for granted as an axiom, and he anticipates Newton, to a certain extent, by pointing out the universality of gravitation not merely on the earth, but in the moon also. It appears he made use of magnifying glasses to a limited degree, arranged, perhaps, like a crude telescope, for he was in a position to study the spots on the moon more closely than could be done with the naked eye, as appears from this sentence in his notes Mc C A Fol 190r: " Construct glasses to see the moon magnified." Among his conclusions on cosmic problems are the following:

" The earth is a star." Ms F Fol 56r—Ms C A 111b: 345b

" The sun does not move." Ms W L Fol 132r

" I say that the moon has no light in itself and yet is luminous, it is inevitable that its light is caused by some other body? and again so much of it (the moon) as faces the sun is illuminated and of that illumined portion we see so much as faces the earth, etc., etc." Ms Bm Fol 94v



Works of defence—moats, parados, redouts, galleries, etc.

" Beyond the sun and us there is darkness and so the air appears blue." Ms W XXVI

" Every man is always in the middle of the surface of the earth and under the zenith of his own hemisphere and over the centre of the earth." Ms Tr 28

" Take the measure of the sun at the solstice in mid-June " Ms Bm Fol 78v; referring to the observance of an eclipse without pain to the eye, he says: "Take a piece of paper and pierce holes in it with a needle and look at the sun through these holes." Ms Tr Fol 6v(12)

He refers to the equator, the line of the horizon, the ecliptic and the meridian, saying of them: " These lines are those which in all their parts are equidistant from the centre of the globe." Ms Bm 176a

Referring to the stars, he says: " The stars are visible by night and not by day because we are beneath the dense atmosphere, which is full of innumerable particles of moisture, each of which by itself when struck by the rays of the sun reflects a radiance, and so these innumerable bright particles conceal the stars, and if it were not for this atmosphere the sky would always display the stars against its darkness." Ms F Fol 5v

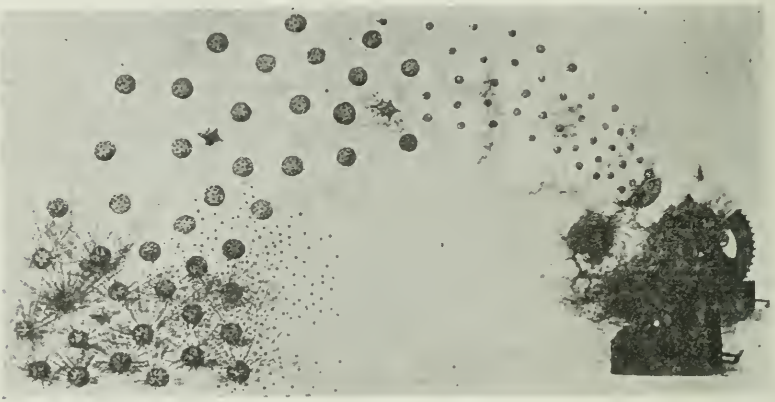
GEOLOGY.

In the field of geology and physical geography, Leonardo found much that aroused his interest, much that was mysterious and inexplicable, but he endeavored to formulate reasons for what he saw and he made abundant observations in his notes, statements from which it appears that he was far in advance of his time. We find interesting and extended comments in his notes on the probability of a universal flood having covered the earth, and reference to the finding of sea shells and other fossils on the tops of high mountains where the shells, being heavy objects, could not have been carried by the sea. Ms Leic Fol 9v. In discussing this problem he displays a remarkable knowledge of the physical geography of many parts of Europe as he does when he discusses the ebb and flow of the tide and the height of the rise of the tide in various places. There is also a very interesting and extended presentation of the subject of why the water in the sea is salty; discussions on the relative areas of sea and dry land and the relation of the sea to vast subterranean water courses, in which he was a firm believer. The origin and flow of rivers, the elevation of the earth into mountains and their erosion into valleys, and the origin of wind and waves all occupy his attention, and he gives a wealth of observational details to substantiate his opinions as to the causes of the various phenomena. " The water wears away the mountains and fills up the valleys, and if it had the power, it would reduce the earth to a perfect sphere."—McCurdy, LdV Note Books, Page 101 from Mss C A 185 v c. How he obtained such an enormous amount of observational material covering the physical geography of practically the whole of the then known world, is one of the many mysteries surrounding the manuscripts which have not received an adequate explanation.

The notes contain records of many exploring excursions to the lakes and mountains of northern Italy, and there is a record of a genuine alpine ascent of Monte Rosa—with its peaks reaching a height of over 4600 metres (15,000 feet)—and he gives a careful description of the height of the clouds, the extent of the snow in the summer season, effects of hail, etc.

BOTANY.

As a painter, studying with care the landscape and the effects or light and shade on the verdure of trees and plants, he was quite naturally led to study the various forms of trees, the division of the branches and the form and arrangement of the leaves. While he refers to these in his "Treatise on Painting," he calls attention to the fact that he would treat the science of the trees and plants, *i.e.*, their botanical relations, elsewhere in his manuscript. We find pictured in his notes, particularly in the series in the Windsor collection, a number of flowers and leaves, with the outline of their form, petals and stamens reproduced with scientific precision, rendering any description quite unnecessary. Leonardo found that the leaves of plants grow on the twigs in an invariable order. "The branches of the plants grow on the limbs just as the leaves grow on the twigs of the same year; the leaves have four methods of growing above each other: The first and more general arrangement is that the sixth always grows above the sixth which is underneath it; the second arrangement is that the two that are the



Mortars and exploding shrapnel.

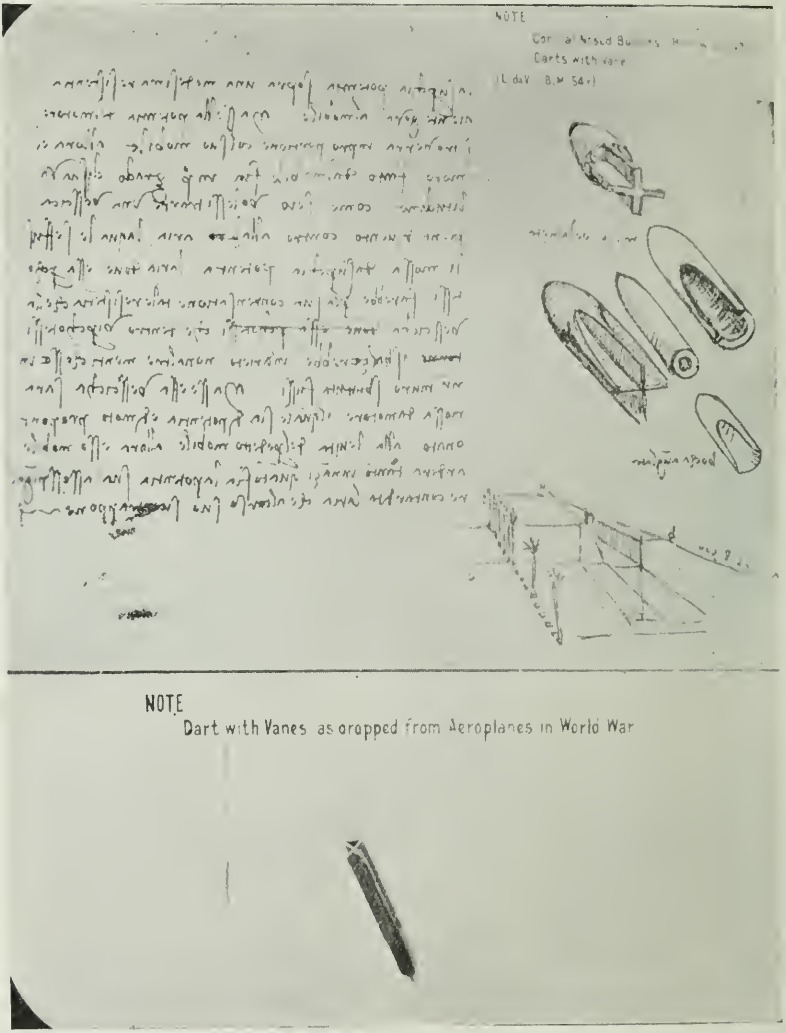
third ones on top are above the two that are the third ones underneath; and the third arrangement is that the third one on top is above the third one that is underneath." Ms G 33a. Leonardo has thus observed the law that an unvarying number of leaves separate each leaf from those which vertically precede and follow it. He omits to give the fourth method of growth, but in another note, regarding the elder tree, he points out the case of opposite leaves which grow two and two (the lilac). In text-books on botany the credit for discovering these regular arrangements of leaves is usually assigned to others under a much later date.

He gives as the reason for the regular arrangement of the leaves on the branches: "Nature has so placed the leaves of the latest shoots of many plants that the sixth leaf is always above the first, and so on in succession, if the law is not accidentally interfered with. This is of a two-fold advantage to the plants; first, as the branch or the fruit, the year following, grows at the axil of the leaf the rain which falls on the branches can drop and nourish the bud, these drops being held in the cavity formed by the axil of the leaf; and the second advantage to the plant is that when its branches grow the following year, the one does not cover the other, because the five branches grow turned in five different directions and the sixth grows above the first at some distance." Ms G Fol 16v. Passing over some interesting observations as to the arrangement of the limbs on the main trunk of trees and the relation of the combined cross section of the branches to the cross section of the limbs as determined by the flow of sap, we come to the most important of all, that Leonardo first discovered that by the annual ring growth of trees their ages could be determined; the relative thickness of the rings indicating wet or dry seasons, and the eccentricity of the rings indicating their relation to the points of the compass.

ANATOMY AND PHYSIOLOGY.

In no department of human knowledge has Leonardo done more important research work, exhibited more distinctly modern tendencies, and combined in such remarkable manner his abilities as an artist-illustrator and scientific investigator, than in the realm of physiology and anatomy, particularly the latter.

As a painter he speaks everywhere of the absolute necessity of a complete knowledge of the anatomy of the human body, its structure, proportions, and muscular development, but in his scientific researches and dissections of human cadavers he went far beyond


NOTE
Conical Nosed Bullets [illegible]
Darts with vane
(L da V B.M 54 r)
NOTE
Dart with Vanes as dropped from Aeroplanes in World War

Conical bullets and darts with vanes—dart with vanes dropped from aeroplanes in the World War.

the requirements of a sculptor or painter and interested himself in observing the structure, relations and functions of every organ of the body. Unfortunately, his notes and sketches on anatomical subjects, as in fact on every subject they touch upon, are distributed in a fragmentary form throughout his manuscripts, although most of them appear on the sheets brought together in the Windsor collection and recently splendidly reproduced in six large folio volumes by three learned specialists under the auspices of the University of Christiana. The reproduction consists of magnificently executed facsimile sheets, a transcription into the original Italian, and parallel translations into English and German.

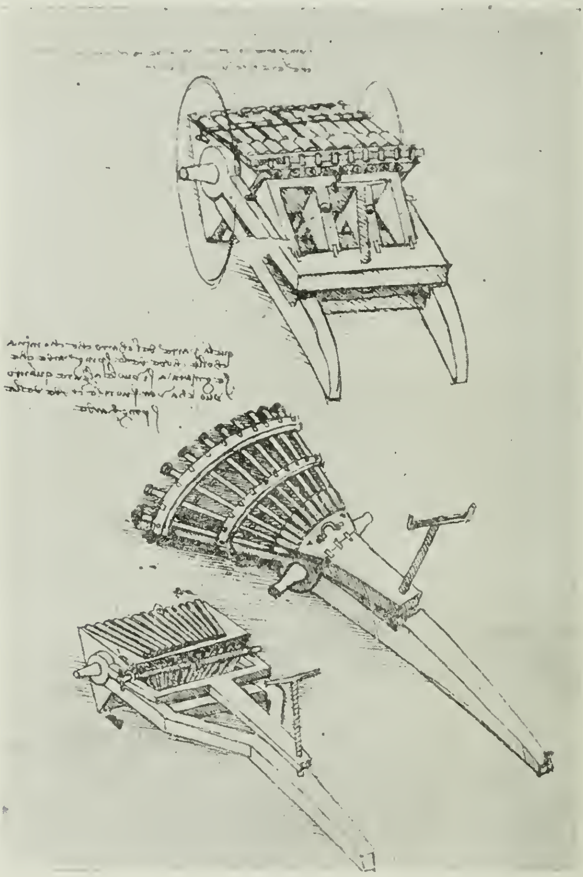
It will be difficult to assign to Leonardo his proper place as a pioneer worker in this special field, but with this recent publication he has come to be generally recognized by the medical profession as the founder of Physiological Anatomy. Dr. William Hunter, an eminent authority, had previously said that "Leonardo was at that time the best anatomist in the world. His studies of the bones and muscles are exhaustive and he considers them not only in their individual structure, but in their interrelationship and combined functioning."

A recent commentator on his work, from the medical profession, has said: "Imbued with the importance of the static and mechanic laws to which the human frame is subjected he rises to the most modern standards of illustration which the painstaking work of the past decades has evolved. The way in which he draws the normal curvature of the spine, adjusts his skulls with intention in a definite horizontal plane, and fixes the pelvic inclination, would make one think that he adopted the standards decided upon in the latest anatomic and anthropological congresses. He illustrates the complex action of antagonistic muscle groups by means of tape models, the schematic drawings of which at once elucidate flexion and extension, pronation and supination. He also knows the advantages of clear demonstration to be derived by serial cross sections, which he employs on a lower limb. By appropriate sections through the skull, he shows most beautifully the pneumatic sinuses and their interrelation, a demonstration which no anatomist up to modern times had attempted."

In method Leonardo was the forerunner of both Vesalius and of William Harvey, and although Leonardo knew the difference between the arteries and veins and that the blood circulated throughout the body, he did not, however, discover the law and processes involved in the circulation of the blood which was discovered later by Harvey.

He was familiar with the authorities and quotes from Mondino's Anatomia, and must have known of Galen's work, as he did of that of the learned Arab doctors.

At a time when the church taught the sacredness of the human body and was ready to excommunicate those who practiced dissection, he pursued his studies relentlessly, and it was owing to an information laid against him concerning these experiments that the Papal favor was withdrawn from him and he was obliged to leave Rome in 1515. Let us reproduce a few of his anatomical notes: Speaking of the desirability of watching an anatomical demonstration rather than studying a drawing, he says:



Metrailleuse.

"If only it were possible to observe all the details shown in these drawings in a single figure; in which, with all your ability, you will not see nor acquire a knowledge of more than some few veins, while in order to obtain an exact and complete knowledge of these I have dissected more than ten human bodies, destroying all the various members and removing even the very smallest particles of the flesh which surrounded these veins, without causing any effusion of blood other than the imperceptible bleeding of the capillary veins." Ms WAN IV Fol 167r

"With a saw (dissection) cut through a head at the eyebrows to find the reason of the simultaneous movement of the two eyes, etc."

"Write in thy anatomy what proportion there is between the diameters of the lenses of the eye, and the distance from these to the crystalline lens." Ms CA Fol 345v

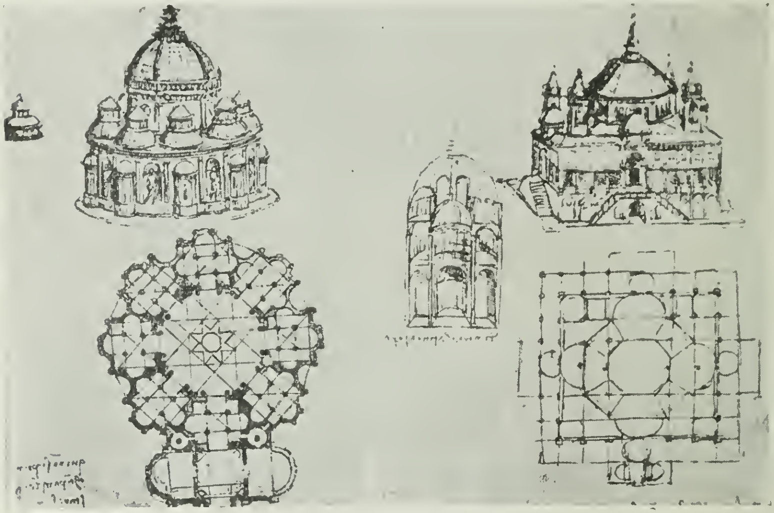
"Who would believe that so small a space could contain the images of all the universe? O mighty process! What talent can avail to penetrate a nature such as thine? What tongue will it be that can unfold so great a wonder? Verily none! This it is that guides the human discourse to the considering of divine things. . . . Here the figures, here the colors, here all the images of every part of the universe are contracted to a point. O what a point is so marvelous!" McCurdy, L.d.V. Note Books, page 117, from Ms CA. 345vb

"Walking of man is always like the universal manner of walking of quadrupeds. As they move their legs diagonally like a horse in trotting, so man in walking moves his four members diagonally; that is, if he puts forward his right foot in walking, he brings forward at the same time his left arm and vice versa." Ms CA Fol 297r

"The death of old men, without fever, is caused by the veins, which, going from the spleen to the liver, have their skin become so thick that they close and no longer give passage of the blood which nourishes them. The continued flow of blood in his veins caused the veins to become thick and callous so that at last they close and prevent the blood from flowing." "An old man, a few hours before his death, told me that he had lived a hundred years and that he did not feel any bodily ailment other than weakness, and thus while sitting upon a bed in the Hospital of Santa Maria Nuova at Florence, without any movement or sign of anything amiss he passed away from this life. And I made an autopsy in order to ascertain the cause of so peaceful a death, and found that it proceeded from weakness through failure of blood and of the artery that feeds the heart and the other lower members which I found to be very parched and shrunk and withered; and the result of this autopsy I wrote down very carefully and with great ease, for the body was devoid of either fat or moisture, and these form the chief hindrance to the knowledge of its parts. The other autopsy was on a child of two years, and here I found everything the contrary to what it was in the case of the old man." Ms WAN B Fol 10v

Leonardo's special attention was drawn to the heart and lungs and he made numerous cross sections of the heart, particularly the bovine heart, and he distinguishes the two ventricles and the two auricles and characterized the heart as a muscle, the first in strength and potentially among all the other muscles. It is difficult to understand why, with the knowledge of Dynamics and Hydraulics he possessed, he did not discover the whole mechanism of the circulation of the blood, and this mystery is deepened by the sentence appearing in his notes: "Do not the veins of the lungs send back to the heart the blood, when they contract to expel the air?" Klebs, Leonardo da Vinci, page 12.

The nervous system also passed under his scalpel and his whole dissective technic is a marvel even to the modern surgeon. Note, for instance, the representation of the brain ventricles by a cast obtained through injection of wax into the third ventricle and his suggestion of "putting eye balls into white of egg, to coagulate them, and then make sections for the study of the eye." Klebs, LdV, his Anatomical Studies, page 14.



Architectural designs for church.

It is said that he dissected more than thirty bodies of men and women at various ages, besides many animals. No one before him represented in drawing the muscles, organs, and nerves as he did, and his anatomical work throughout is characterized by astonishing accuracy, deep physiological insight, and zealous endeavor to get at the facts.

We must dismiss at once the thought that his anatomical work was undertaken and recorded merely for artists and not for medical students and for the professional anatomist.

CHEMISTRY.

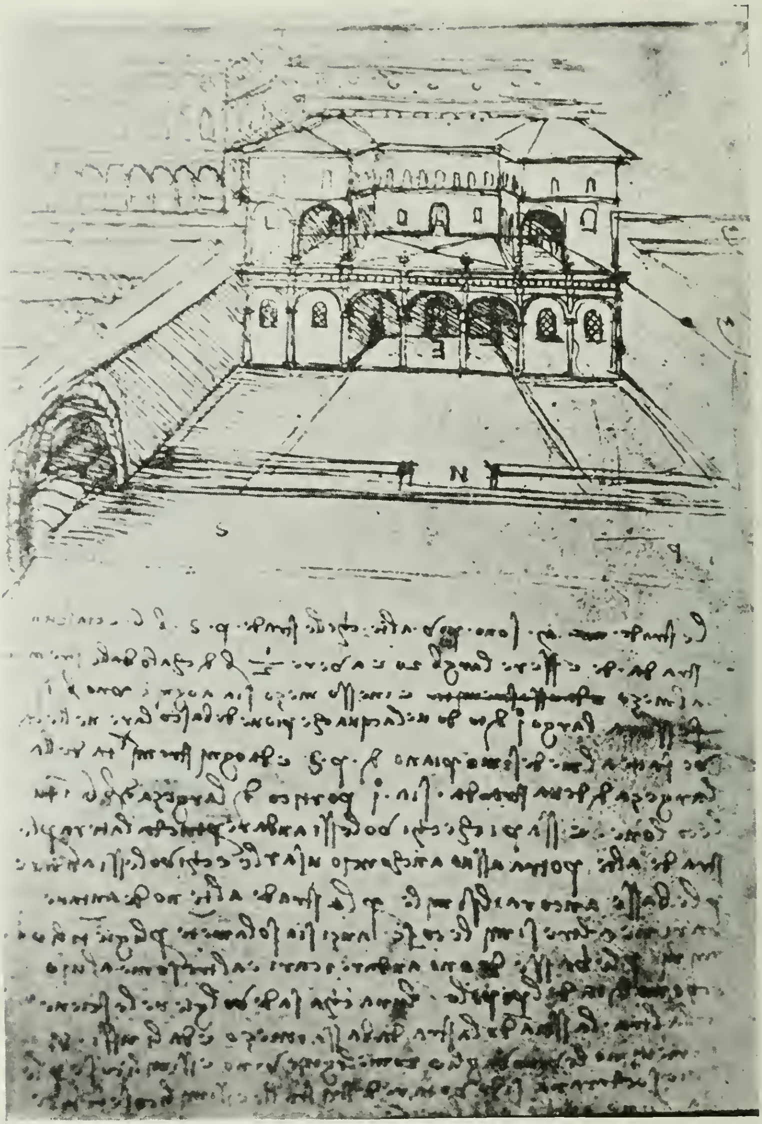
An inspection of the facsimile drawings show many sketches of chemical retorts, stills and furnaces which he used in experimenting with the various recipes he gives for perfumes, oils, the preparation of colors and varnishes, acids for etching metals, mixtures for fireworks and poisonous gases. He illustrates a carefully designed reverberatory furnace and a still with condenser provided with a constantly flowing stream of cold water. But of all his chemical observations the most interesting are those relating to the burning flame, and here he is several centuries ahead of his time in outlining the theory of the processes of combustion in the candle flame.

His notes say: " Where flame cannot live, there breathing animals cannot. The light (candle) flame creates a vacuum and air rushes to relieve the vacuum. Elementary fire continually consumes the air by which it is partly nourished and would find itself in contact with a vacuum if the surrounding air did not rush in to refill it. Smoke is generated in the middle of the flame from the candle." Ms C A Fol 237v. " Flame arranges first the matter by which it is nourished and then nourishes itself thereon. Excessive wind destroys flame, a moderate wind nourishes it." Ms C A Fol 270r

His ceaseless dabbling with oils and preparations to be applied to fresco paintings is no doubt responsible for the loss to the world, as asserted by some of his contemporaries, of two of his great masterpieces, " The Last Supper " and " The Battle of Anghiari," both ruined—the former partly, the later utterly—by defective application of the tempera or oil to the wet plaster, resulting in its peeling off very rapidly.

GEOMETRY.

As we examine the manuscripts we find portrayed an infinite number of figures made up of circles, cusps and interlaced figures of circular segments, literally many thousands of them, with every conceivable combination of a line and circular arc that could possibly be inscribed in a circle. What could have been the purpose of these curious diagrams, whether they were studies which had a scientific aim or were meant to serve an artistic or practical purpose, we do not know, but they have been made the basis of many interesting decorative designs of rosettes and architectural ornaments.



Model city plan—upper and lower level streets.

The manuscripts contain references which indicate Leonardo's interest in arithmetic, algebra, geometry and mechanics—and his notes abound in computations which indicate a facility in making use of formulæ and in making calculations in mechanics and physics. He is said by competent authority to have invented the plus (+) and minus (−) signs and other notations, such as the use of letters of the alphabet for numbers and combinations thereof, etc., which are still in use. He sought a method to develop curved surfaces on a plane, to distinguish between lines of single and double curvature, and proceeded on the basis that surfaces were the limits of all bodies and lines the limits of surfaces. One of the geometric propositions he lays down is: " The largest sphere which can be inscribed in a given cube has a surface equal to the largest cylinder which can be inscribed in the same cube."

He coöperated with Luca Paccioli in preparing his work, Divina Proportione, which undertook to apply to the human body, to architecture and to the construction of the letters of the alphabet, certain basic geometric proportions, and Leonardo executed the drawings in which inscribed polyhedrons are marvellously shown in perspective.

In addition to these geometric designs we find a number of figures involving complicated rope-like labarinthine interlacings, such as we often see in more simple form in connection with illuminated initials, an example being a kind of trademark or seal marked " Leonardi Academia Vi-ci," presumably for the Academy which he is said to have founded at Milan, but of which we have very little knowledge.

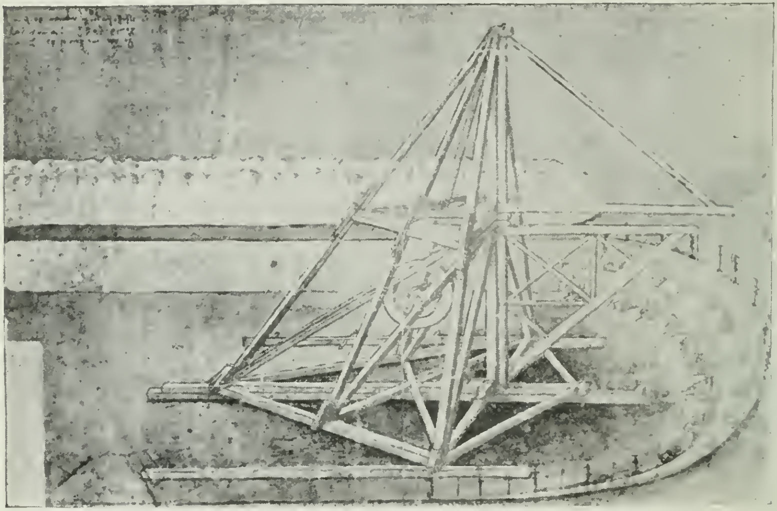
PHYSICS.

It is in the department of physics and particularly of mechanics of which he said: " Mechanics is the paradise of the mathematical sciences, because through it one reaches the fruition of the mathematical sciences," Ms E Fol 8b, that the great master has displayed to particular advantage his extraordinary reasoning faculties and his complete control of research and experiment in deducing the fundamental laws by a process of inductive reasoning, in the application of which he undoubtedly antedated Bacon.

In connection with his work as a painter he became much interested in the phenomena of light and shadow—umbra and penumbra—and his notes contain innumerable sketches of sources of light with bodies of different shapes which in interference cast shadows of different shapes and degrees of density.

A series of interesting studies on sound, its propagation in air, in liquids and in solids, its reflection, production of echoes, etc., is presented to us in the notes. The discussion of force, impact, pressure and velocity in their relation to mechanics and dynamics, occupies many sheets, and his experiments and calculations are supplemented by numerous diagrams and sketches.

"Why the thunder lasts for a longer time than that which causes it; and why immediately on its creation the lightning becomes visible to the eye, while the thunder requires time to travel, after the manner of a wave, and makes the loudest noise when it meets with most resistance."—McCurdy, LdV Note Books, Page 92 from Ms. K 110 (30) v.



Excavating machine for canals.

The numberless arrangements of pulleys and cords, in every imaginable combination, and calculations of weights and equilibrium of the systems lead up to the practical employment of these arrangements in lifting and hoisting machines of various kinds and in powerful rope mechanism for the tensioning of beams and springs for stone and dart-throwing engines of war.

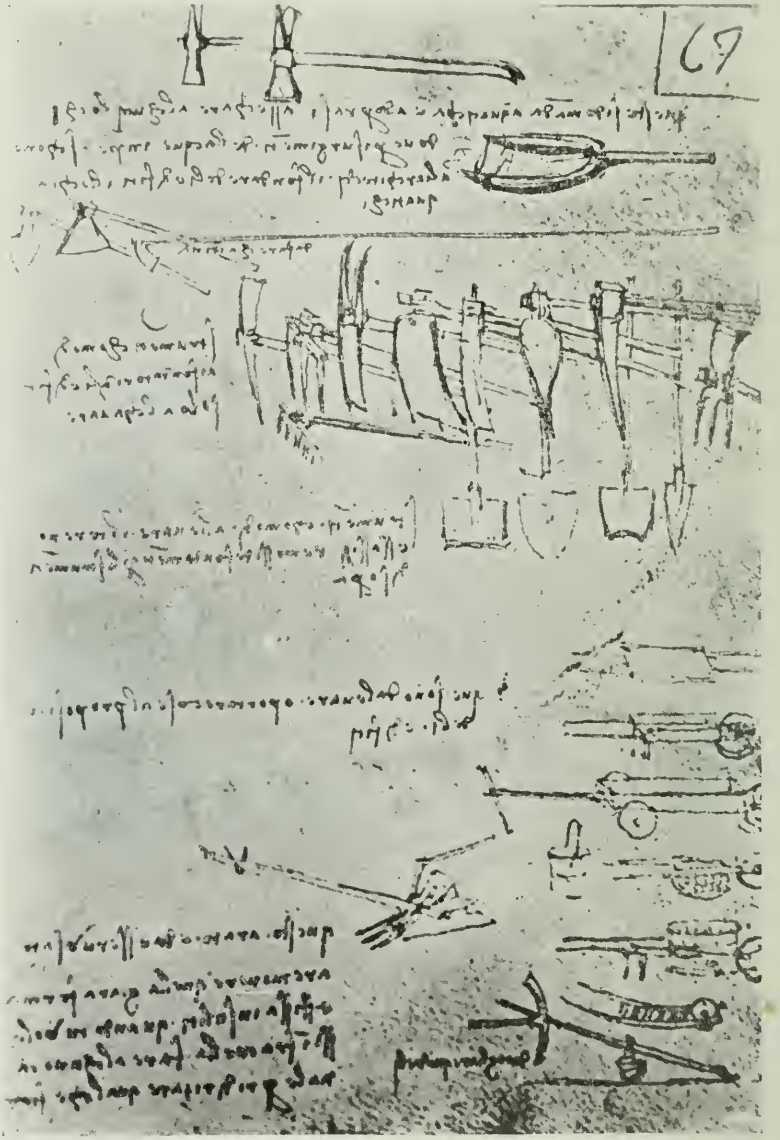
His constant aim to establish laws or rules based on his experiments and investigations lead him to generalizations which, while they may not always be scientifically exact in the light of modern science, nevertheless bear evidence of acuteness of observation and are expressed in terse phraseology. We note, for instance, the following:

> "If a given force moves a weight a certain distance in a certain time, the same force will move the half of the weight the same distance in the same time or the whole force will move all the weight in half the time half the distance, or the whole force in half the time will move all the weight half the distance." Ms F Fol 26v. "Force never has weight, but it always has the effect of weight." Ms CA Fol 382r. "Among wheels of the same diameter that one will be most easily revolved which is supported by the smallest shaft." "The friction of bodies is of as many different degrees as are the degrees of lubricity of the bodies which are rubbed together. In those bodies of which the surfaces are smooth, friction is least. In bodies of equal lubricity the heavier body offers the greater resistance in friction. Every body resists in friction with a power equal to one-fourth of its weight, the planes being level and the surfaces smooth." L.d.V and his works, Heaton and Black, p. 151.
>
> "Where there is more contact there is more resistance, and the teeth of the square screw have a larger surface than the triangular (V) teeth; it is there that the screw with the triangular teeth responds more readily to a movement, because it has less contact and resistance."

In mechanics Leonardo knows not only the theory and resolution of forces applied to the lever and oblique forces, but the resistance to the propulsion of ships as influenced by the form of the submerged body, the influence of the centre of gravity on bodies at rest and in motion, and most important of all, he clearly establishes the broad principle of virtual velocities, the basis of the modern science of analytical mechanics.—Wilhelm Elsässer, Bedeutung L. d. V. für die Exacten Wissenschaften. Preuss. Jahrbücher, 1899.

We find also some experiments on steam and its application, making use of its pressure, for instance, in a steam gun, the "architonitro," and also to move a weight or piston. It remains to speak of perpetual motion for which we find a number of designs of apparatus of types that have come to be well known, but Leonardo frequently emphasizes the absurdity of achieving perpetual motion and cries out: "O Speculators about perpetual motion, how many vain chimeras have you created in that quest? Go and take your place with the alchemists."

We have referred to Leonardo's services as a Military Engineer and that he was an expert in every then known branch of military science appears from page after page of his manuscripts.



Construction tools: Picks, shovels and evolution of the wheelbarrow.

MILITARY SCIENCE.

We have, first of all, portrayed a remarkable series of engines of war of the general types used by the ancients—catapults, balaestre, mangonels and cross-bows. The majority of these weapons are based on the bending of heavy wood or metal springs or the torsional power of twisted rope, the tension being applied by screw gearing, levers or pulley blocks, operated in the very large machines by animal power.

Cannon were coming into use and he shows in great detail the methods of making the cores and moulds for casting cannon, designs for the breech-blocks of breech-loading cannon, and in one case pictures a complete cannon foundry with cranes in operation and workmen in action in poses full of energy as he alone could sketch them. We find not only cannon of heavy and light calibre, but revolving cannon of the type of the metrailleuse and multi-barrelled guns mounted on gun carriages, some of them of truly modern design.

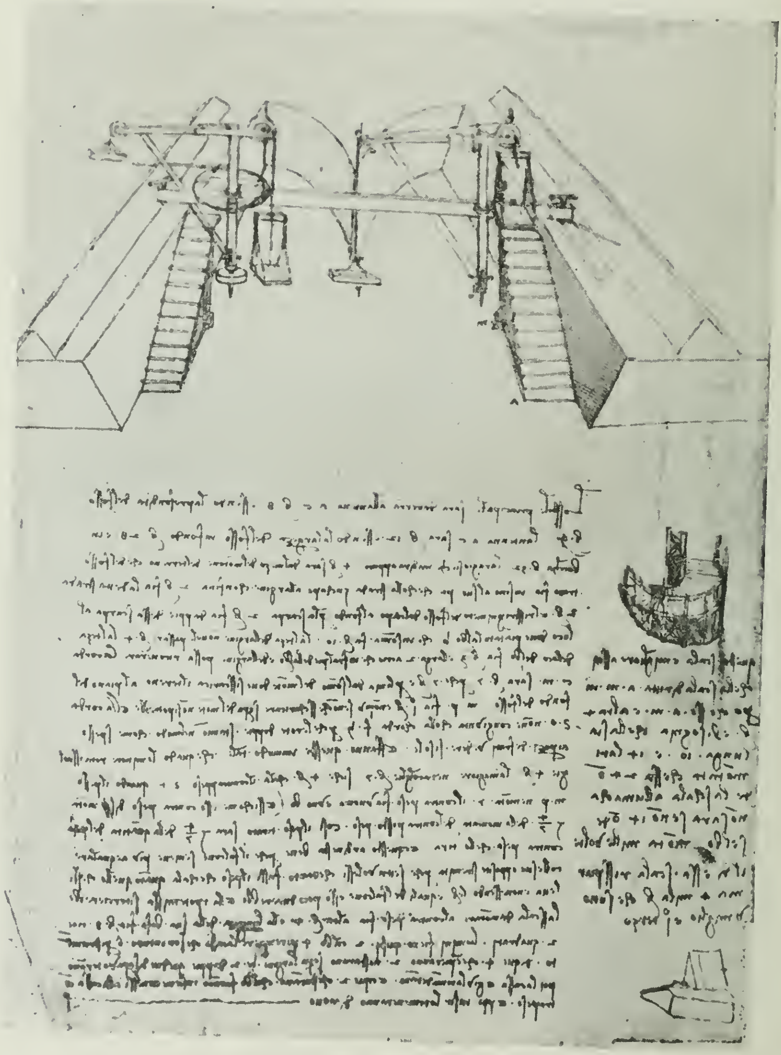
We find pictured and described various types of two and four wheeled vehicles, for one and two horses for the transportation of subsistence and the various other services rendered by the military train.

But we must express our admiration for the built-up gun with accurately fitted, tapered steel bars, wire-wound into a compact barrel, and the very highest mechanical skill is shown in a very complete and altogether modern appearing machine operated by water power for automatically drawing these tapered trapezoidal bars.

These machines are shown in detail with their principal working parts appearing on an enlarged scale, so that they constitute complete working drawings in accurate perspective.

An extended series of sketches of ancient and medieval hand weapons covers several sheets and they appear in complete and orderly arrangement, each spear, battle axe, pike or slung shot carefully sketched and its method of use indicated. We find here and there sketches of flying military bridges for crossing moats and canals; and also drawbridges, pontoons and folding bridges that fold into the side of the canal so as not to impede navigation.

There appear numerous outlines of fortresses, fortified castles, and defensive works, some of them of the polygonal type carried out in completeness of detail that suggests a Vauban. We have a suggestion of the competition between the offensive power of cannon and the defensive resistance of brick, concrete, and earth works in the statement, "Because the artillery of to-day have increased in power by three-quarters, one must also increase the resistance of the walls by three-quarters," Grothe, LdV als



Canal excavating machine.

Ingenieur and Philosoph, p. 65, and again in speaking of brushwork shields for fortification of walls, he says:

> "That blow will be of greater force which is given against a resisting barrier and so is returned; that will be the weaker which meets a barrier of less resistance. Thus it follows that rigid walls do not withstand heavy blows, but hay and sod in which the fury of balls driven from powerful cannon is absorbed, do withstand the blows." Ms CA Fol 41va

We have illustrated grape-shot, chain-shot, shrapnel, including conical and pointed shot and bullets, and the advantages of the latter are discussed with a reference to the helical rifling of cannon. There would appear to be a reference to cartridges in these words:

> "The mounted carabineers must be provided with slender and simple tubes full of powder, with the ball inside so that they can be readily inserted and in this way an immense number of the enemy will be vanquished, and these carabineers must form in squadrons the same as arbalesters so that one part of them can fire while the other loads; but first be sure to accustom the horses to these noises or better stop up their ears."

One of the sheets shows a collection of ladders of all kinds, evidently intended for military use in scaling walls, and on another page we have exhibited a scheme for repulsing the besiegers by overthrowing them from the wall by thrusting out a hidden wooden framework. We have illustrations of attacking ships by the use of Greek fire by fire-boats and by sinking ships with a boat equipped with a submarine projecting ram in reference to which he says:

> "Why is it that I do not describe my method of remaining under water? How long can I stay without eating?—these I do not publish or reveal on account of the evil nature of men, who would practice assassination on the bottom of the seas, by breaking the hulls of boats and wrecking them with all on board; while I tell about other means of submergence there is no danger from these because on the surface of the water there appears the mouth of the aspiration tube floating on skins or cork." Ms Leic Fol 27b

He is quite familiar with mining and countermining and gives curious instructions for detecting the noise made by the sappers in their operations.

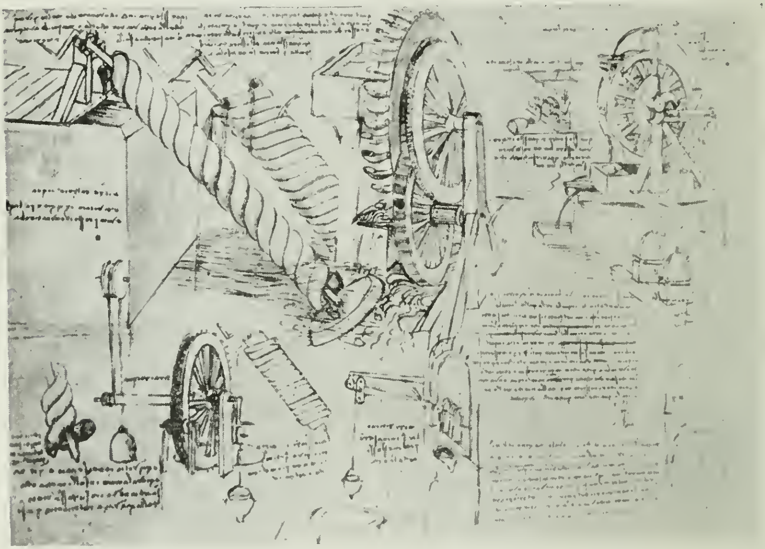
But we must be particularly interested in the anticipations of a number of instruments of warfare that were conspicuous in the World War, such as the defensive steel headgear, the defensive breastplate and movable shield, the tank—yes, and poisonous gases and gas masks, as well, for we find the following note:

> "Throw among the enemy ships, with small catapults, chalk, pulverized arsenic and verdigris. All who inhale this powder will be asphyxiated by

breathing it, but be careful that the wind be such as not to blow back the fumes, or else cover your nose and mouth with a moist cloth so that the powder fumes cannot penetrate." Ms B Fol 69v

CIVIL ENGINEERING.

Some of the excellent drawings, many of them colored, appearing in the manuscripts are maps and topographical plans of various kinds, probably sketches for use in connection with his plans for canals and irrigation works. Of the utmost interest is a map indubitably by the hand of Leonardo to which has been assigned the date 1513–1514, found among the manuscripts of Windsor. In a report entitled "Memoir on a Mappemonde by Leonardo da Vinci," by N. H. Major, Esq., F. S. A., he states as to his map:



Water lifts—Archimedian screw.

"First: That it is the earliest map yet made known to the world on which the name of America stands inscribed.

"Second: That it is the earliest known map on which the severance of the western coasts of America from their previously supposed continuity with Asia is recognized.

"Third: That it is the only map, as yet known, which contains an indication of the early fancied existence of a great Southern continent anterior to the discovery of Magellan's Straits, etc."

(*To be concluded*)

DISPOSAL OF INDUSTRIAL WASTES AND STREAM POLLUTION.*

BY

C. A. EMERSON, JR.
Chief Engineer Pennsylvania Department of Health.

PROPER methods for disposal of industrial wastes, which consist of liquids contaminated by the process of manufacture, are essential for prevention of stream pollution or stream despoliation.

Official action to control the discharge of these wastes has not been taken in most instances until after nuisance conditions have arisen or damage has been done to lower riparian owners.

Several general reasons may be advanced for this disregard of public rights by owners of industries and apparent lethargy on the part of government officials; an unfortunate lack of appreciation of the damage to be caused by discharge of the various kinds of industrial waste; former ignorance as to economical and effective methods of treatment; reluctance to make expenditures for installation and maintenance of treatment works when such expenditure might seriously affect the profits of the industry and lastly—want of uniform and definite control legislation.

The result of this delay is particularly noticeable in an industrial State such as Pennsylvania. Even now many of our large streams are so grossly polluted by industrial wastes that their return to a condition of reasonable cleanliness is a task of great proportions, but one which is by no means insurmountable.

The cost of treatment of industrial wastes to prevent stream pollution should undoubtedly be borne by the industries responsible for the discharge. Unfortunately the majority of these wastes are refractory and many of the treatment processes are expensive and relatively inefficient. The enactment of rigid control legislation is only a portion of the remedy and might easily place such a burden upon the industries as to seriously disturb the prosperity of the State. Economical and effective methods of treatment must be developed and proven by actual plant operation before we are ready for stringent legislation.

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* Presented at a meeting of the Mechanical and Engineering Section held Thursday, March 3, 1921.

The owners of the industries, as a rule, recognize their moral responsibility and are ready to install treatment processes when it can be shown that there is reasonable assurance of success at a not prohibitive cost.

Methods of treatment which have been developed in the past have oftentimes been unsatisfactory either because of the expense of the treatment process or else because of misconception of the character and degree of treatment required.

There was formerly a tendency to believe that most industrial wastes could be given treatment of the same general character and that all processes should be carried to such a degree of refinement that the effluent discharged into the stream would be clear, colorless, tasteless and free from chemical and bacterial poisons. The judgment of to-day is upon a more rational basis and takes into consideration the great variation in the physical and chemical composition of the different wastes requiring special treatment processes; the relative values of the industries to the State; the present uses and probable future development of the water course and the ability of the stream to absorb and purify the waste by natural agencies.

Another forward step has been the realization that many of our industrial wastes contain matters of value and that improved methods of manufacture which make fuller and better use of the raw materials not only lessen the cost of the commercial product of the industry but reduce or even entirely remove a portion of the objectionable characteristics of the industrial waste, thus simplifying the methods and lowering the cost of treatment.

To secure the desired results requires joint investigations by engineers and chemists, backed by the coöperation of the manufacturers, and preferably under the guidance of the State, for the benefits derived react on the prosperity of the entire Commonwealth.

These principles can well be illustrated by considering methods of treatment now in use or in process of development for some of the more common industrial wastes.

You are doubtless familiar with the objectionable appearing and nuisance producing wastes from tanneries. These wastes have been studied for years, and the development from the first crude settling basins, installed and then promptly neglected, is interesting. Tannery waste carries much matter in suspension; may be alternately acid and alkaline in reaction; is objectionable in color and because of its avidity for oxygen and its active chemical constituents will cause a nuisance when discharged into a small stream. In line with the principle of conservation, it has been found that the spent tan liquors discharged from the vats can be concentrated by evaporation and again used in the tanning process. Much of the hair from the hides, which was formerly wasted, is now being reclaimed by flotation combined with fine screening, and has a ready market. The waste from the lime vats is settled in properly designed and carefully operated sedimentation basins, and the sludge is either dried or is dried and also recalcined and used as a fertilizer. The bits of flesh scraped from the inside surface of the hides are used by glue manufacturers. After the removal of these various objectionable constituents, the liquid waste remaining can oftentimes be discharged into a city sewer system or into a large stream without causing nuisance, or if the receiving body of water is so small or its uses are such that further treatment is required, the liquids can be subjected to precipitation by chemicals or the organic matter oxidized through violent agitation by compressed air and subsequently removed by sedimentation. The resulting effluent is free from objectionable color and is sufficiently stable to prevent the creation of a nuisance when discharged into a small stream.

Disposal of the liquid wastes from wool scouring plants, without creation of a nuisance in streams, has been furthered by development of processes for recovery of the grease removed from the wool in the cleaning process. Formerly the grease was recovered by treating the wastes with either naphtha or sulphuric acid, but recently centrifugal separators have been installed, similar in principle to those used in dairies for separating cream from milk, and are operating with marked success. The results obtained at one of the wool scouring establishments in the vicinity of Philadelphia may be taken as an illustration. The total liquid wastes of the plant amount to approximately 10,000 gallons daily. Of this volume, about 7000 gallons are contaminated with grease from the wool and are passed through the separators, yielding from 180 to 200 pounds of wool grease or crude lanoline a day, which is sold to the refiners at a price representing a desirable profit over the cost of operating the separators. Of equal importance to the sanitarian, the liquid wastes after removal of the grease, are susceptible of treatment by sedimentation and sand filtration at a moderate cost.

The wastes from the tar separators, the ammonia, benzol and naphthalene stills of by-product coke ovens and the wastes from gas works employing the water gas method of production, while not ordinarily polluting streams to a sufficient degree to cause objectionable conditions to those residing along the banks, are of particular importance because of the disagreeable tastes which these wastes impart to the water when used for domestic purposes. The types of water filtration plants in general use by municipalities will not remove the disagreeable tastes from a raw water contaminated by these wastes or by the products caused by the chemical combination of the active principles of the wastes. In fact, chlorine treatment of the water supply, which is in almost universal use as an adjunct to water filtration, apparently serves to accentuate rather than to diminish the objectionable taste. After application of chlorine, in the minute quantities ordinarily used in treatment of public water supplies, the tastes have been noticeable in dilutions as great as one part of the wastes to ten million parts of water. Treatment of these wastes, to be effective, must, therefore, be most complete. Fortunately, such method of disposal is now available and consists, simply, in excluding all such wastes from streams used as sources of public water supply.

At the coke ovens, all of the objectionable and taste producing liquid wastes are collected and used for quenching or cooling the glowing coke drawn from the ovens, thus passing into the air in clouds of steam. As an excess of the water is sprayed over the coke at a high rate, a portion is not evaporated at once, but passes through the coke into sumps beneath the quenching platforms and is recirculated by pumps to be evaporated during quenching subsequent charges of coke. Incidentally, the finely divided coke, formerly carried into the streams and lost with the excess quenching water, is now deposited in these sumps and salvaged, representing a saving which offsets the additional cost of operation of the circulating pumps. At the largest by-product coke oven installation in Pennsylvania the volume of contaminated water thus turned into steam is in excess of one million gallons daily.

At the gas manufacturing plants equally effective methods of disposal are in vogue. Waste waters from the gas washing chambers are freed from their burden of suspended tars and oils by passage through sedimentation and skimming tanks and the effluent water is recirculated through the process to again extract oil and tar from the gas. The oil and tarry deposits in these tanks form the base for the road oils so widely used on our highways and represent a considerable income to the owners of the works. At one of our large Pennsylvania plants where operation methods did not permit of constant recirculation of the water and would at times have permitted excess waste water to pass to the river, thus reducing the effectiveness of the entire treatment process, the difficulty was remedied by using this excess water in the plant boilers, after it had been modified by sedimentation and coagulation, followed by filtration through coke strainers and sand filters. As this gas company purchases boiler water from the city system, and as the labor cost at the sand filter is nominal, the saving in the water bills is gratifying to officials of the plant.

Other wastes productive of much trouble are those from oil refineries and from oil wells. The installation of settling basins provided with skimming weirs have been of value in separating oil from the wastes from refineries and form a source of considerable profit to the owners. In certain oil producing districts large volumes of salt water are pumped to the surface with the oil, and this is particularly true when the oil wells are nearing exhaustion. The salt water discharged into the streams, after removal of the oil, causes salinity sometimes almost equaling that of the ocean. The remedy to date in Pennsylvania has been simple and effective, consisting merely of the discharge of the salt water back into the well outside the pump casing, thus preventing stream pollution and using the salt water as a medium for bringing more oil to the surface.

A form of stream pollution which formerly caused much complaint in certain portions of the great iron industry districts was due to the discharge of the so-called "acid-iron" or "pickling" liquors—that is, the waste from the process of acid cleaning of rust and scale from metal prior to tin plating, galvanizing or other surface treatment of plates or tubes. When the strength of the acid had been reduced to such a degree that it was no longer effective for rapid removal of rust and scale it was the practice to discharge it into the streams, which caused destruction of fish life and also rendered the water unfit for drinking by livestock in the pastures or for boiler or other manufacturing purposes. These wastes consist principally of ferrous sulphate, with some free sulphuric acid and ferric sulphate. They are now evaporated in acid-proof tubs, in the presence of iron turnings to neutralize the free acid and to reduce the ferric to ferrous sulphate, producing the crystalline ferrous sulphate of commerce. This procedure entirely prevents the discharge of waste acid from the pickling process, thereby abating the stream pollution.

Another interesting feature of waste disposal occurs in one of the branches of this general industry, the tin plate mills, where large quantities of palm oil and ordinary grain middlings are used in cleaning and polishing the tin plate. The palm oil has nutritive value, and as much of it is absorbed and retained by the middlings during the cleaning process, they are not discarded but are returned to the grain dealers and sold as cattle food. The mill owners simply pay what amounts to a rental charge for use of the middlings.

The most serious and extensive source of stream pollution in Pennsylvania is that due to the discharge of coal mine drainage, both from the anthracite and from the bituminous fields. The total volume of this waste is enormous. It has been estimated that over 850,000,000 gallons of water are pumped from mines in the anthracite fields each day, and that the volume pumped or flowing from mines in the bituminous regions of the State approximates 600,000,000 gallons daily. The total volume of this mine waste is about four times the volume of water furnished each day by the Philadelphia city waterworks.

The total quantity of free acid and acid salts carried by these mine wastes and by the discharge from the washeries has been estimated at over 3000 tons each day. It is impossible to even roughly estimate the total damage caused each year by this mine drainage, but recounting some of the havoc caused will serve to emphasize the seriousness of this pollution. The deposit on the stream beds of the fine coal carried by the mine drainage obstructs the normal flow channels, causing blockage of sewer outlets and increasing flood damage during high water periods. The sediment and the acid reaction destroy fish life. The increased hardness of the stream water is materially adding to the difficulty and expense of maintenance of at least ninety-six public waterworks in the State, supplying water to over 3,775,000 people, or nearly 45 per cent. of our total population. The increased cost to navigation, to industry, to municipalities and to individuals in the Pittsburgh district alone, has been placed at over $8,000,000 annually. The difficulties incident to control of this drainage are apparent when we consider that, exclusive of many small wagon mines, there are in the neighborhood of twenty-six hundred active mines in Pennsylvania, and, furthermore, that discharge of mine drainage is not restricted to active mines, but also occurs by water continuing to flow from abandoned mines and by rain water falling upon the great culm and waste piles carrying acid drainage and fine material into the streams.

Mine drainage is not by any means uniform in chemical composition nor in physical appearance. The acid content varies widely in different districts and even from mines in relatively close proximity. Another striking difference is that the water of mine drainage polluted streams in the bituminous regions is relatively clear in appearance and ranges from a light yellow to a reddish brown in color, whereas the streams of the anthracite region carrying drainage from the mines, the breakers and the coal washeries are black and opaque in appearance, due to the great quantities of finely divided coal which they carry.

No exact figures are available for the tonnage of this coal which has been discharged into the streams flowing from the anthracite regions. It is possible, however, to derive approximate figures which are startling. The excess in coal taken from the ground over that marketed during the last sixty years has been estimated to be more than 500,000,000 tons. This excess was either allowed to escape into the streams or was placed in great storage or culm banks near the mines. As the contents of these culm banks is believed to have been approximately 125,000,000 tons, we are forced to consider that the difference between these figures, or 375,000,000 tons, represents the quantity of coal which has escaped into the streams from the mine fields.

Fortunately this enormous wastage does not represent a complete economic loss, for much of this coal has been deposited on the beds and along the banks of the streams and reclaiming operations have been practised for years along the Susquehanna, the Schuylkill, the Lehigh and their tributaries. The prevailing method for reclaiming the coal along the main streams is by small suction dredges, which pump a mixture of sand, coal and water from the bed of the stream. The discharge of the pump is over a screen, having six or eight meshes to the inch, and which serves to restrain the marketable coal while the finest particles of coal and much of the sand pass through the screen and are wasted. The cost of reclaiming and marketing this "river coal," as it is called, is moderate, and it is much in demand, not only for use in large industrial boiler plants but in private homes. The shortage in freshly mined coal during the past three years has served to greatly increase the recovery of river coal and figures recently made public by the State Topographic and Geological Survey indicate that a total of about 2,000,000 tons were reclaimed from our streams during 1920.

The increased cost of mining coal and the profits accruing from the simple dredging operations just described are causing the mine operators to realize that the coal now wasted by the wet process breakers and by the washeries should no longer be discharged into the streams. Furthermore, the need for some method of treatment whereby mine water can be successfully used in the breakers, obviating the great expense of pumping non-acid water long distances or the present high replacement costs due to the corrosive action of acid water, is each year becoming more apparent. A general idea of the volume of water required at the one hundred or more anthracite breakers can be obtained when we consider that approximately one gallon of wash water is required a minute for each one ton of the daily coal output, and the damage due to use of acid waters in the breakers may be estimated from the statement that annual replacement and repair costs of twenty thousand dollars at a single large breaker are not unusual.

Within the past two years several plants designed to eliminate the present coal wastage have been installed in the anthracite region. The process is, essentially, separation of the fine coal by sedimentation and can be further developed by neutralization of the acid by lime treatment to render the mine water suitable for use in the breakers. The sedimentation tanks are of the radial flow type, and the effluent is discharged over a weir around the periphery. Slowly revolving, radial arms sweep the sedimented particles to a small discharge opening at the apex of the inverted cone forming the bottom. The fine coal thus removed from the basins is passed through mechanical concentrators or classifiers, similar to those in use in lead, zinc and copper mining. Operating results at one of these coal recovery plants will serve as an illustration of the general process. Slush, after being wasted by the finest screen of a modern wet process mine breaker, a screen having holes three-sixty-fourths of an inch in diameter, passes through the recovery plant at a rate of about 3500 gallons a minute and yields approximately 150 tons of usable coal a day. The effluent of this particular sedimentation basin is freed of materials which would be retained on screens having sixty meshes to the lineal inch, or approximately one-half the total weight of suspended solids in the breaker slush. Other basins are designed and operated to remove all solids which would be retained on a one-hundred-mesh screen. If desired, the wastes from the first set of basins and the concentrating tables can be passed through secondary basins for removal of all readily settleable materials, producing a clear effluent. It should be stated, however, that materials removed by such supplementary sedimentation would be mostly silt and particles of coal too fine for present market purposes.

It has been estimated that universal installation of settling basins of the type described, or others similar in function, would increase the coal output of the anthracite region by about 3,000,000 tons annually. Such increase would not only represent substantial profits to the mine owners, but, to a very considerable degree, would reduce the conspicuous and damaging stream pollution of these regions.

A generation ago the development of this method of freeing breaker and washery wastes from the fine particles of coal in suspension would have had little value, for there would have been no market for the salvaged coal. The combustion engineers who developed practical methods for using powdered coal as a fuel, successful procedure for briquetting coal and improved design of mechanical stokers have paved the way for this process of coal conservation.

For the neutralization of the acid mine drainage to permit its use in the breakers of the anthracite region and for quenching coke in the bituminous fields, we can turn to a method in successful and profitable use in the western part of the State. A few years ago at one of the coke burning villages the supply of neutral water for quenching purposes was insufficient during droughts, and as all the streams in the vicinity were so contaminated with mine drainage that use of the water would discolor the coke and increase its sulphur content, thus materially decreasing its market value, the engineers and chemists of the mining company undertook the neutralization of the acid stream water with limestone to produce a suitable water for use at the coke ovens, thus conserving the meagre supply of non-acid water in the reservoirs for domestic and power purposes.

These experiments have resulted in a plant which is treating upwards of one million gallons of mine water a day by addition of finely powdered limestone to neutralize the free sulphuric acid and to decompose the ferric sulphate into ferric hydrate. The sludge thus formed is removed by a sedimentation basin, similar to that described for removal of fine coal from drainage of the anthracite regions, and is then freed of excess moisture by a steam heated revolving dryer. The effluent water is sufficiently low in sulphur and iron to use for quenching coke and by virtue of the process the ovens at this mine have been operated during dry seasons when other mines in the vicinity were handicapped by a shortage of water. The dried sludge from the basins, containing ferric oxide, amounts to about seven tons a day and is in constant demand by manufacturers of artificial gas for use in removing the hydrogen sulphide present in such gas. It is stated that the revenue from this plant is materially in excess of the operating cost, thus furnishing the company with an additional water supply of approximately one million gallons a day at little or no expense. Experiments are now under way for a further development of this by-product, for example, as a substitute for the iron oxide in paint pigments and utilization of the phosphorus and potassium constituents in soil fertilization.

Even though feasible and profitable methods have been developed for removing the fine coal from the wastes of the anthracite region and for neutralization of the free acid of the wastes of both the anthracite and bituminous regions, we have not by any means solved the mine drainage problem. The enormous quantities of lime which would be required for neutralization of the acidity of drainage from all of the mines, together with the moderate market for the resulting product place limitations upon the wide adoption of this method. Furthermore, it is faulty in one essential feature, the effluent is not freed of the incrusting constituents and hence is not suitable for either boiler or domestic water supply purposes, even after passage through fine grained sand filters. It has previously been stated that some ninety-six water supplies of the State are now difficult of purification because of mine drainage pollution of the raw water, and this number is certain to grow as additional mines are opened, contaminating streams now free from acid drainage and increasing the contamination of streams at present receiving only moderate volumes of such drainage.

The most successful method yet devised for neutralization of acid mine drainage and for removal of the boiler scale forming constituents makes use of barium carbonate, which reacting on the sulphates formed by previous addition of lime, results in the relatively insoluble barium sulphate, which can be removed by filtration, giving a clear and soft water. At least three such plants are in operation in the west and are stated to produce a superior water for boiler purposes. Unfortunately, the barium salts are expensive and, of more consequence, they are poisonous. There is no absolute guarantee that the barium will always be entirely precipitated when used in treatment of a water contaminated by a combination of mine drainage with other wastes which are acid in reaction, especially in the event of accidental and unforeseen conditions of filter plant operation. Its use, therefore, for treatment of water intended for human consumption cannot be justified.

The absence of a satisfactory method for complete treatment of mine drainage is not because the problem has been neglected by able investigators, but rather is due to the fact that, in the past, studies have been directed at only a single aspect of the problem, and when the particular objective had been reached the search was abandoned.

This is equally true in the case of other industrial wastes; for instance, there have been studies to develop methods of treatment of certain wastes to prevent nuisance in the case of discharge into a large body of water, other studies to prevent destruction of fish life, and numerous others simply to recover single products of value which had been wasted.

Within the past few years various government departments and bureaus and the scientific staffs of large industrial establishments throughout the world have undertaken comprehensive studies of methods of disposal of many industrial wastes. The object of these studies has been two-fold: first, to recover products of value from the wastes, and second, in case such products did not exist or could not be extracted by any method known to science, to develop some economical process for modifying the wastes so as not to prevent any legitimate uses of the receiving body of water and to determine the limitations of the method of disposal selected.

Only since the inception of this class of investigations has real and definite progress been made.

The industrial prosperity of any State may safely be said to depend upon a suitable and adequate water supply. With the tendency to concentration of our industries, the local needs for such water supplies will increase, requiring even greater progress to be made in solution of industrial waste disposal problems. Investigations made thus far demonstrate that the goal can be reached only through refined methods of manufacture to make use of all possible elements of value in the raw materials and also methods of treatment which will recover all products of commercial value in the industrial wastes in order to partially or even wholly offset the cost of treatment of the portions which are without value.

Progress towards this end has been rapid and the future is bright. Therefore, it appears that the creation of nuisance in streams and the destruction of their usefulness through lack of proper disposal of industrial wastes has passed the peak, and that in a few years such improvements in the general condition of the surface waters of our industrial states will be obtained that they can be economically used for all legitimate purposes.

Action of Sodium Sulphide on Ferric Oxide.—By the reaction of finely divided ferric oxide with crystalline sodium sulphide, a black amorphous substance is formed. After the major portion of the sodium sulphide has been removed, the residual mass yields a brilliant green solution; the color is due to a colloidal iron compound which contains neither sodium nor sulphur in its molecule. The colloid is precipitated by a relatively large amount of sodium sulphide, also by complete removal of the sodium sulphide by either dialysis or oxidation. The green solution contains less than 0.07 gram iron per litre, and cannot be dialyzed in the presence of air. If air be drawn through the solution until the sodium sulphide is oxidized to sodium sulphate, the color of the solution changes to brown, apparently due to the formation of a colloidal hydrated ferric oxide which finally precipitates. (J. C. Witt in *Journ. Am. Chem. Soc.*, 1921, xliii, 734–740.)

J. S. H.

TIDAL OBSERVATIONS OFF THE ENTRANCE TO DELAWARE BAY.*

BY

H. A. MARMER.

Coast and Geodetic Survey, Washington, D. C.

Our knowledge of the time and range of the tide away from the coast is extremely meagre, since tidal observations have been confined almost wholly to the immediate vicinity of the coast. Any attempt, therefore, at presenting a comprehensive view of the tides, as for example that involved in the construction of a cotidal map of the world, is necessarily based on theoretical considerations upon which agreement is not yet unanimous. Hence all tidal observations made at some distance from the coast are of considerable value.

It is this that lends particular interest to a series of accurate tidal observations covering a period of 40 hours, made on the southern end of Five Fathom Bank (latitude 38° 50.7′ N, longitude 74° 37.8′ W), about 18 nautical miles east of the entrance to Delaware Bay on Sept. 28–30, 1920. These observations were made in connection with offshore precise dead-reckoning hydrography, by the party of the U. S. Coast and Geodetic Survey Steamer *Bache,* Capt. H. A. Seran, commanding.

The apparatus used for measuring the rise and fall of the tide was a very simple one, but gave quite accurate results. It consisted of a tide staff, one inch square and ten feet long, secured to a float and confined in a two-inch pipe 33 feet long. The pipe was ordinary stock galvanized pipe made up in sections about twelve feet long, with the bottom section cast in an 800 pound block of concrete. To keep the pipe upright, it was moored by No. 6 galvanized wire to four concrete blocks weighing somewhat more than half a ton apiece, placed about 100 feet from the bottom of the pipe.

To eliminate wave motion it was decided to admit the tide near the bottom. But it was also necessary to place the opening high enough to prevent clogging by sand or other matter. The opening was, therefore, made in the bottom section of the pipe about seven feet from its junction with the concrete base. The tide staff was graduated to feet and two-tenths, the figures increasing downward, so that the height of the tide was read directly at the top of the pipe. As arranged, the tide staff could be read from the ship at some distance from the tide gauge.

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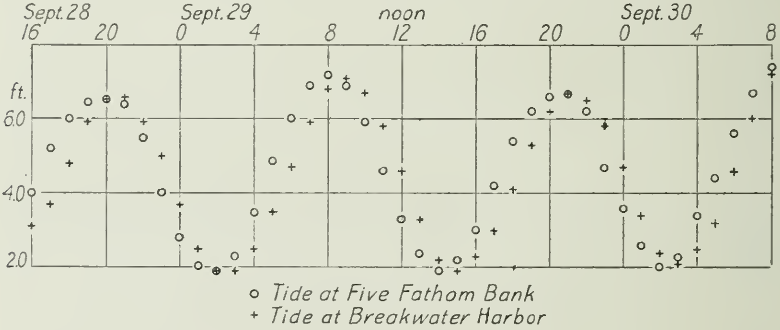
* Communicated by William Bowie, Chief, Division of Geodesy.

The height of the tide was read every hour and is here shown plotted on cross-section paper, the circles giving the hourly heights of the tide as read. The curve is seen to be the regular semi-daily tide curve. For comparison there is plotted the hourly height of tide (indicated by crosses) as read from an automatic tide gauge record operating simultaneously at Breakwater Harbor, Delaware, just inside Delaware Bay, and about twenty-three miles from Five Fathom Bank.



The range of the tide appears to be almost exactly the same as at Breakwater Harbor. For the period of observations at Five Fathom Bank the range was 4.9 feet, which reduced to a mean value by comparison with a long series of tidal observations at Breakwater Harbor, makes the mean range 4.3 feet.

From the simultaneous observations plotted here, the time of tide at Five Fathom Bank is 45 minutes earlier than at Breakwater Harbor. This is somewhat less than the time required for a free wave to travel the distance of twenty-three miles over the average depth of 8½ fathoms between Breakwater Harbor and Five Fathom Bank.

Based on these observations the cotidal hour for Five Fathom Bank is about XII.2. In this connection it is interesting to note that on the cotidal maps of the world, constructed by Dr. R. A. Harris,[1] the XII hour cotidal line is slightly to the west of Five Fathom Bank. In constructing the cotidal lines offshore, Doctor Harris was compelled to rely wholly on theoretical considerations, which in this case are well borne out by the tidal observations.

Manufacture of Aircraft, 1919.—A preliminary statement of the general results of the 1920 census of manufactures with reference to aircraft has been issued by the Bureau of the Census, Department of Commerce, furnishing a detailed statement of the quantities and values of the different types of aircraft manufactured during the year 1919, prepared under the direction of Mr. Eugene Hartley, Chief Statistician for Manufactures.

Reports were received from 31 establishments engaged in the industry during 1919, showing products for the year valued at $14,372,643, as compared with 16 establishments in 1914 with products valued at $789,872. Of the 31 establishments reporting for the year 1919, 10 were located in New York; 4 in Ohio; 2 each in California, Massachusetts, and Missouri; and 1 each in Connecticut, Indiana, Illinois, Louisiana, Maryland, Nebraska, New Jersey, Pennsylvania, Rhode Island, Washington, and West Virginia.

The following is a summary of statistics of the industry for 1919, the "All other products" reported consisting chiefly of airplane parts, engines, and repair work.

Summary of Statistics of the Aircraft Industry, 1919.

Number of establishments	31
Total value of products	$14,372,643
Airplanes:	
Number	432
Value	$3,466,452
Seaplanes:	
Number	230
Value	$4,580,016
Value of work done during year on airplanes and seaplanes not completed	$1,658,670
All other products, including parts and repair work	$4,667,505

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[1] See Cotidal Lines of the World (Manual of Tides, Part IVB), by R. A. Harris, Washington, D. C. 1904.

Chemical Industry in the Argentine Republic.—Three Argentine companies manufacture sulphuric acid (53°–56° Baumé) by the chamber process with imported sulphur from Italy, Chile, and the United States. There is a great demand for Sicilian sulphur, being of greater purity, and burning without ash. Transport of sulphuric acid by sea is very difficult, owing to long voyages in the tropics, the home industry being thus favored. Nevertheless, local works find it difficult to compete with imports.

Nitric and hydrochloric acids, the first in commercial degrees (38 and 42), are manufactured from Chile saltpetre and native salt. Chemically pure sulphuric and hydrochloric acids are also manufactured. The main part of the acetic acid imported is glacial, at 99°. Two works near Cordoba produced pyroligneous products by dry distillation of algarrobo wood, chiefly lead and lime acetates, acetone and acetic acid, which are more expensive than imports. However, the demand exceeds the supply. Local production of tartaric acid is limited to one or two vineyards, wine-lees being obtained in large quantity at Mendoza. In 1916 the United States began to export this acid to the Argentine. During the last eight years imports of citric acid from France, England, Germany, and Italy, represented an average of 132 metric tons per year. The United States commenced exports in 1914. The acids sell better in crystals than powder. Imports of phenol are very irregular; England is the chief source. Tar oil acids are preferred for washing cattle. The oils should contain at least 10 per cent. phenol, and some manufacturers say 25 per cent. Boric, hydrofluoric, and tannic acids and carbon dioxide are also from Germany, France, England, and, since 1916, the United States has supplied a certain amount of carbon dioxide, which is also manufactured locally in breweries. Imports of alum, which were more than 6300 metric tons from 1913 to 1916 fell to 490 tons during the last two years. The United States imports now represent 50 per cent. Hydrated alumina is employed to a limited degree for lakes and colors, textiles and glass. Large quantities of home-made aluminum sulphate are employed to purify drinking water. Local manufacture is only one-quarter of the imports. Ammonia solution is chiefly imported. The average imports during the last seven years were 540 metric tons per year, 90 per cent. being from America Liquid ammonia is chiefly English. Arsenic and arsenical compounds are employed for glass, insecticides, and colors. The demand is for white, yellow, and red arsenic (99 per cent.), in barrels of 200 kilograms, and lead and sodium arsenates in boxes of 5 kilograms. The United States now heads the list of imports.—(*Chimie et Industrie,* through *Chem. News.*)

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

FIRE TESTS OF BUILDING COLUMNS.[1]

By S. H. Ingberg, H. K. Griffin, W. C. Robinson and R. E. Wilson.

[Abstract.]

This is an experimental investigation of the resistance of columns, loaded and exposed to fire or to fire and water, with a record of characteristic effects, conducted in coöperation with the Associated Factory Mutual Fire Insurance Companies and the National Board of Fire Underwriters, the tests being made at Underwriters' Laboratories.

Method and Scope.—The fire exposure was produced by placing the column in the chamber of a gas-fired furnace, whose temperature rise was regulated to conform with a predetermined time-temperature relation. Measurements were taken of the temperature of the furnace and test column and of the deformation of the latter due to the load and heat.

The test columns were designed for a working load of approximately 100,000 pounds, as calculated according to accepted formulas. The amount varying somewhat for the different columns. The working load was maintained constant on the column during the test, the efficiency of the column or its covering being determined by the length of time it withstood the combined load and fire exposure.

In the fire and water tests, the column was loaded and exposed to fire for a predetermined period, at the end of which the furnace doors were opened and a hose stream applied to the heated column, the severity of the test being regulated to correspond with the degree of resistance developed by the corresponding type of column in the regular fire tests.

The paper reports on 106 tests of columns, of which 91 were fire tests and 15 fire and water tests.

The series includes: (1) tests of representative types of un-

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* Communicated by the Director.

[1] Technologic Paper No. 184.

protected structural steel, cast iron, concrete-filled pipe and timber columns; (2) tests wherein the metal was partly protected by filling the reëntrant portions or interior of columns with concrete; (3) tests wherein the load-carrying elements of the columns were protected by a 2-inch or 4-inch thickness of concrete, hollow clay tile, clay brick, gypsum block, and also, single or double layers of plaster on metal lath; (4) reinforced concrete columns with 2-inch integral concrete protection.

The covering materials for each class of protection were obtained from the main producing regions of the country, the object being to include samples from the principal mineralogical subdivisions that find general application in building construction. A large number of auxiliary tests of constituent materials were made, which are described and results given in a separate section with the aid of diagrams and 30 pages of tabulations, forming a fairly comprehensive source of information on the physical and chemical properties of the materials used in modern fire-resistive construction.

In placing the columns and coverings, the work was planned so as to reproduce as nearly as possible the conditions obtained in building construction, in point of methods of application and workmanship. This was done to make the results of the tests applicable without undue allowance for differences that otherwise might be deemed to exist between the test column and a similarly constructed member in a building.

Test Results.—These are presented in 12 tables and 128 figures and diagrams, the latter comprising views of columns before and after test, the time-temperature curves for the furnace and 6 to 12 points on the test column, and unit deformation with corresponding average column temperature curves. Test logs give detailed developments during each test.

The results in point of time to failure in the fire test are studied with reference to size of column, and for given column and covering materials, relations are established between fire resistance and area of solid material in the column cross section. The test results, supplemented by investigations on the properties of the column materials under heat and load, also afforded means for determining the useful limit of a column when loaded and exposed to fire. A summary of general characteristics of the column and covering materials, as developed in the fire tests and the auxiliary tests, is made, which can in part be applied to building members other than columns. A summary is given of methods used and results attained in previous investigations and an effort made to interpret the latter with the aid of the information now available.

Fire Resistance Periods.—The results of the tests are finally summarized in terms of hours and minutes of fire resistance afforded by the different types of columns and protections tested. The resistance period is taken as a portion (two-thirds) of the average time to failure in the fire tests, the deduction being made to allow for incidental variations in material and workmanship of columns and coverings as tested and as installed in buildings and also for differences in load and fire conditions that cause variations in results with nominally comparable columns. Requirements relative to resistance to water application are limited to ability to sustain load without danger of immediate collapse in case of fire recurring after fire and water exposure. Application of the results is extended beyond the particular materials tested as far as existing knowledge of the properties of related materials justifies it, this being done to give the results greater continuity, Interpolation is also made for a covering thickness intermediate between those tested.

The resistance periods thus derived vary from 10 minutes for unprotected structural steel columns to 8 hours for similar columns covered with 4-inch thickness of concrete made with fire resistive aggregates and reinforced concrete columns made with the same aggregates. Filling the reëntrant portions or interior of structural steel columns with concrete gave them resistance periods ranging from ½ hour to 3½ hours, depending on the size and shape of the column and the concrete aggregates employed. Single-layer protection of plaster on metal lath applied to structural steel columns gave ¾-hour resistance, and double layer, with airspace between layers, 1½ hours. Two-inch concrete protection on structural steel columns gave resistance periods from one hour to four hours, depending on the aggregate employed. The concrete made with sand and pebbles high in silica (chert and quartz) developed disruptive effects on exposure to fire, which is ascribed (1) to points of abrupt volume change existing for chert as low as 210° C. and for quartz at 573° C. where it is transformed into the mineral tridymite; (2)

to disruption of the pebbles from evaporation of the chemically combined water of the chert, and water occluded in tiny cavities in the quartz when it crystallized. Concrete made with trap rock, granite, sandstone, or hard coal cinder aggregate proved superior to that made with siliceous gravel. The highest resistance obtained with concrete made with dolomitic limestone and calcareous sand. The 4-inch concrete protections developed resistance periods from 2½ to 8 hours, the variation with the aggregate being similar to that for the 2-inch protections.

Hollow clay tile on structural steel columns gave periods from one hour to 3 hours, depending on the type of clay and method of application. Tile made from semi-fire clay burnt to medium hardness developed greater freedom from cracking and spalling than any other tile tested. Hard burnt semi-fire clay tile evidenced greater effects from fire exposure, and with surface clay and shale tile these disruptive effects were very marked. Little or no difference in resistance was noted as between the 2-inch and 4-inch thickness of hollow tile, the time to failure being dependent on the area of solid material rather than on the thickness of the air space. Filling the interior with concrete or tile appreciably increased the resistance and stability of the covering, and interior metal ties were found to be superior to outside wire ties in holding the tile in place. Solid clay brick set on end and edge to form a solid covering about 2½ inches thick outside of the steel proved somewhat unstable on exposure to fire and developed a resistance period of only one hour, while with brick laid flat in the usual manner to form a 4-inch covering thickness, 5-hour fire resistance was developed. Solid gypsum block, 2 inches in thickness, laid outside of flanges and edges of structural steel columns and with space between blocks and flanges filled with gypsum mortar, gypsum blocks, or poured gypsum filling, gave 1½-hour resistance, and similar coverings made with 4-inch solid blocks gave 3½-hour resistance, the failure being due in all cases to shrinking, checking, and disintegration of the blocks which caused them to fall off and expose the steel.

Round hollow cast iron columns developed 20-minute fire resistance as tested unprotected, and ½-hour resistance when unprotected and filled with concrete. Protections approximately 2 inches in thickness and consisting of Portland cement plaster on metal lath, hard coal cinder concrete, or round porous semi-fire clay tile increased their resistance period to 2 hours. Steel or wrought pipe not smaller than the 6-inch standard size, filled with 1 :4½ concrete gave resistance period of 25 minutes and similar pipe, not smaller than the 7-inch standard size, filled with concrete and reinforced in the fill with structural angles, gave ¾-hour resistance.

Reinforced concrete columns with 2-inch integral concrete protection, gave 5-hour resistance as made with trap rock aggregate, and 8-hour resistance as made with limestone aggregate.

Pine and fir timber columns with unprotected cast iron or steel caps gave 25-minute resistance, with column and cap covered with ⅜-inch gypsum wall board gave ¾-hour resistance, and with protection of Portland cement plaster on metal lath gave 1½-hour resistance. The cause of failure of the timber columns was loss of strength of the wood at the cap bearings due to conduction of heat from the flanges of the metal caps to the bearing plates and into the wood, which caused it to soften, crush, and induce slipping or fracture of the caps. While the fire test reduced the area of the columns by 29 to 55 per cent., their resistance to fire and load outside of the bearings was not fully developed in the tests.

The series fairly covers the range of current practice in structural steel columns and perhaps also, in proportion to the extent of their use, in that of the other column materials except reinforced concrete, which latter is the subject of a special investigation recently completed by this Bureau. The studies made on effect of size indicate that the results obtained with the columns tested, which were representative of the smaller sizes in general use, can be extended with safety to larger columns.

THE WAR WORK OF THE BUREAU OF STANDARDS.*

[ABSTRACT.]

IT has seemed advisable to gather together in one report descriptions of some of the more important military investigations conducted by the Bureau of Standards during the war. This is important for two reasons. In the first place it is essential that as complete a record as possible be kept of the activities of the Bureau during the period of hostilities; and in the second place, many of the results gained through military investigations are equally applicable and important in peace-time work.

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* Miscellaneous Publication No. 46.

The report consists of short descriptions of the various investigations which were carried out, each description being complete in itself and having no reference to the organization of the Bureau or the scientific divisions which carried out the work. It is, therefore, possible to read any one of the sections of the report without referring to any of the others. No attempt has been made to give complete descriptions, and but little data will be found as it was believed better to limit the text of this report to general information and conclusions.

Detailed results of the various military investigations which the Bureau conducted will be found not only in the regular publications of the Bureau of Standards, but in the reports and specifications of the War and Navy Departments, and in the material published by such organizations as the National Advisory Committee for Aeronautics. In almost all cases the Bureau's war work was carried out in close coöperation with these other organizations, and quite frequently the Bureau itself issued no reports on the subject.

A very large number of subjects will be found to be treated, a few of which are as follows: Aeronautic instruments; aeronautic power plants; aircraft materials and construction: such as the relative merits of wood and metals for building airplanes, the best substances for airplane dopes, etc.; balloon gases, including the work which the Bureau performed in connection with the recovery of helium from natural gas; the calibration of testing machines, by which the tests made at various arsenals and munitions plants were referred back to the standards of the Bureau; various chemical investigations, including analyses of ferrous and nonferrous metals, the development of platinum substitutes, the routine testing of soap, oils, and paints, experiments in connection with the prevention of corrosion, etc. Chromatic camouflage and its detection illustrates the application of scientific work in optics to modern warfare, while the description of the investigation of various processes for coking inferior grades of coal illustrates the successful coöperation of the Bureau with other Government establishments, in this case the Bureau of Mines.

In connection with the building of concrete ships, a new aggregate giving a particularly light and strong concrete was developed. Other parts of the report deal with various electrical subjects, such as batteries for automobiles and trucks, electric generators for setting off high explosives, magnetic methods for detection of flaws in steel, testing of special lamps for signalling purposes, and extremely important work in connection with radio telegraphy and telephony, including the development of the radio direction finder, radio instruments for submarines and the electron tube.

The production and testing of precision gages in various munitions plants was one of the important pieces of work conducted by the Bureau and will be found to be briefly described.

Various materials of construction, ranging from metals to leather and rubber, were tested in large quantities and investigations conducted to determine their availability for all sorts of new uses. This work, as well as the more usual testing of structural materials, will be found described in the report.

In connection with the development of various new processes of manufacture in the United States, mention should be made of the work on the production of optical glass, the making of a successful cotton fabric for airplane wing construction to replace linen formerly employed, and aid in the development of a satisfactory laminated wood construction for airplane beams. Many other subjects are included in the report, but the above list is typical.

Illustrations are given showing the apparatus employed in some of the investigations and also various representative specimens, ranging from simple devices to complicated machinery, which were tested by the Bureau.

OSCILLOGRAPH MEASUREMENTS OF THE INSTANTANEOUS VALUES OF CURRENT AND VOLTAGE IN THE BATTERY CIRCUIT OF AUTOMOBILES.*

By George W. Vinal and C. L. Snyder.

[ABSTRACT.]

THIS investigation was begun to study the demands upon starting and lighting batteries in the operation of various types of automobiles. For some months the Bureau of Standards has been working upon specifications for starting and lighting batteries at

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* Technologic Paper No. 186.

the request of the Motor Transport Corps of the War Department. These specifications have now been completed, but it was thought desirable to obtain additional information about the performance of batteries when in actual use on automobiles, to supplement the tests which have been made in the laboratory. By using the oscillograph, photographic records of the current and voltage have been obtained. These photographs show the instantaneous values of current and voltage which cannot be obtained by using the ordinary indicating instruments. The results obtained indicate that at the instant when the starter switch is closed the current delivered by the battery on various cars is higher than has generally been supposed, and that it depends very largely on the inertia of the system. After the starter has begun to turn, the current decreases rapidly, pulsating with the compression in the successive cylinders. Typical records are given for a few of the various makes of automobiles that have been measured. In the course of the experiments additional information was obtained with respect to the operation of the starter system and the engine itself. The results given are intended to be suggestive rather than quantitative measurements of performance. They indicate the possibility of using this method for the study of problems relating to lubrication, ignition, compression, distributor action and changes in fly-wheel velocity. In addition to studying the discharge of the battery, oscillograms were also obtained of the charging current when the engine was running. Measurements were made at several different temperatures and curves showing the effect of relieving the compression by removing the spark plugs are also given. The characteristic curves of five different makes of cars are shown. These cars were in ordinary running condition at the time the measurements were made.

DISCUSSION OF THE NATIONAL ELECTRICAL SAFETY CODE.*

[ABSTRACT.]

THIS handbook contains the revised discussion of the National Electrical Safety Code and forms a companion volume to Handbook No. 3, which contains the revised edition of the rules themselves. The discussion of the rules has been considerably amplified. Many items and suggestions have been included which are not involved in the rules themselves, but which have bearing upon good practice and matters immediately related to the subject of the rules. In addition the endeavor has been made to make the meaning and interpretation of the rules entirely evident and to give in many cases the reasons which have prompted inclusion of particular rules in the Electrical Safety Code. Illustrations have been provided to show the intent and application of a number of rules.

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* Handbook No. 4.

The discussion of the rules follows the order of the rules themselves and is segregated into the four parts dealing respectively with stations and substations, overhead and underground lines, utilization apparatus, and operation of utility stations and lines. There is also a supplementary section dealing with the subject of grounding. The introduction to the discussion includes the results of a survey of pole lines made jointly with the committee on safety rules of the National Electric Light Association in the summer of 1919.

Exchange Professors in Engineering and Applied Science.—There has been for some time a regular annual exchange of professors between individual universities in France and America in regular academic fields, such as literature, history, law, fine arts, economics, etc., but there has never been, as yet, any such exchange in engineering or applied science. These subjects are taught in France by special faculties, not included in existing exchanges with America. Furthermore, the French methods of teaching these subjects are unlike our American methods, for various reasons, based on the history, traditions and sociology of the two countries. The great war showed the importance of engineering in production and distribution, and the many ties of friendship which bind us to France, depend in various ways upon applied science. It should therefore, be of mutual advantage to become better acquainted with each other's ideals and viewpoints, in the study and in the teaching of these great groups of subjects.

With these purposes in mind, the late Dr. R. C. Maclaurin, in 1919, as President of the Massachusetts Institute of Technology, consulted the presidents of six universities on or near the Atlantic seaboard, as to whether they deemed it desirable to coöperate in such a joint exchange of professors with France, on a plan definitely outlined. Their replies being very favorable to the project, a committee was appointed, with one member from each of the seven institutions, to report on the plan, and on methods of carrying it into effect. The committee met in December, 1919, and ratified the coöperative plan with some few modifications. The present president of the committee is Director Russell H. Chittenden, of Yale, and its secretary Dean J. B. Whitehead, of Johns Hopkins.

Since the Institute of International Education, in New York, concerns itself with the interchange of college students and teachers from all parts of the world, the committee requested the Institute's director, Dr. Stephen P. Duggan, to undertake the negotiations between the committee and the French University Administration. The result has been that the French Administration responded very cordially to the offer for the annual exchange of a professor. The French have selected, for their first representative, Professor J. Cavalier, rector of the University of Toulouse, and a well known authority on metallurgical chemistry, to come to America this fall, and to divide his time during the ensuing academic year, among the seven coöperating institutions, namely, Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania and Yale. Although it would have been impracticable to have included a larger number than seven in the American plan, yet it is hoped that other institutions may also derive benefit from the incoming French professor's visit.

The American universities have selected as their outgoing representative for the same first year (1921–22), Dr. A. E. Kennelly, professor of electrical engineering at Harvard University and the Massachusetts Institute of Technology.

If the plan continues to operate as favorably as it has commenced, there should not only be a steady annual exchange of a professor, in these various branches of applied science, but also a steady interchange of advanced students between France and America, in these same fields, to the increase of mutual study, mutual teaching and mutual friendship.

Melting Point of Diphenylamine.—Since diphenylamine is used extensively in the explosive and dye industries, it has become a product of commercial importance. Its melting point is usually given as 54° C. A redetermination of the melting point has been made by Homer Rogers, W. C. Holmes, and W. L. Lindsay (*Journ. Ind. and Eng. Chem.*, 1921, xiii, 314–316), using thoroughly purified diphenylamine and standardized thermometers. Two separate series of experiments gave 52.96° C. and 53.00° C., respectively, as the melting point. Therefore, the value, to the nearest tenth of a degree, is 53.0° C.

J. S. H.

NOTES FROM NELA RESEARCH LABORATORY.*

EFFECT OF STRONG ELECTROSTATIC FIELDS ON THE VAPORIZATION OF TUNGSTEN.

By A. G. Worthing and W. C. Baker.

The general procedure has consisted in noting the rate of change of resistance of a tungsten filament operated in vacuo at some fixed current; first, when exposed to a weak electrostatic field opposing thermionic emission; and second, when exposed to a similarly directed strong electrostatic field. For well-seasoned filaments, the changes in resistance with continued burning, at least for moderate electrostatic fields, are due largely to changes in filament cross section resulting from vaporization. Therefore, any difference in the rate of change of resistance for the two conditions of operation is naturally to be ascribed to the effect of the strong electrostatic field on the rate of vaporization of the material.

The most satisfactory mounting for the filaments studied contained two insulated circuits leading through the stem of a well-evacuated, hard-glass lamp bulb. One of these circuits included the filament to be investigated held straight and taut by springs of larger tungsten wire, in axis of a helical coil of still larger tungsten wire which formed a part of the other insulated circuit. All wires leading into the lamp bulb, as well as all wires within, were of tungsten. All junctions were fused. The strong electrostatic field was obtained by connecting the insulated coil to the negative terminal of a small motor-driven Wimshurst machine while the hot filament and the frame of the machine were earthed.

In the most satisfactory test conducted, a 0.060 mm. filament 3.5 cm. long, mounted in a 6 mm. helix 3.2 cm. long, was operated at 2780° K alternately for several time intervals of equal length, first, with a potential difference between filament and coil of 30 volts, and second, with an average potential difference of 11,000 volts. This latter value corresponded to an electrostatic field strength of 800,000 volts/cm. at the surface of the filament.

The measured resistance platted as functions of time of burning showed a straight line relationship for each interval of burning. The averages of the slopes, four against three, showed no change to within one-half per cent. due to electrostatic field. Hence, we conclude that, for the conditions specified, the effect of the electrostatic field on the vaporization of tungsten is negligible.

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* Communicated by the Director.

According to generally accepted views a filament connected to earth becomes deficient in negative electrons when exposed to a steady negative electrostatic field. This means that there exists in the filament an excess of positive ions during the continuation of the electrostatic field. These are probably located on the surface and may here be called " surface ions " to distinguish them from the very temporary ions throughout the filament which are the counterparts of the temporary free electrons. A field strength of 800,000 volts/cm. mentioned above, means a " surface ion " density of 44×10^{10} ions/cm.,^{2} one atom of every 70,000 surface atoms being ionized.

Due to the pull of the electrostatic field these positive " surface ions " might be expected to be more easily detached, that is to be more readily vaporized than neutral surface atoms. Just what forces are called into play and how they are directed is difficult to say since we have no way as yet of determining whether these " surface ions " sustain the whole or only a part of the pull of the electrostatic field on the filament. Thus (1) the tubes of induction from the coil may terminate only on surface ions; (2) the tubes may terminate indifferently on neutral atoms and surface ions, with a readjustment of the tubes within and between the atoms of the filament; or (3) the tubes may congregate in bundles with relatively a large portion of them terminating on " surface ions," and with the remainder terminating on neutral atoms, but with a selective tendency for atoms in close proximity to " surface ions." On supposition (1) the " surface ions " sustain the total pull due to the electrostatic field; on supposition (2) the pulls sustained by a surface ion and a neutral atom are equal; on supposition (3) the pull sustained by the " surface ions " is intermediate between those sustained in cases (1) and (2).

Supposition (3) seems most probable. Some speculation on the basis of (1), however, is perhaps permissible, since in that case the computations, in addition to entailing only a moderate amount of labor, will likely give some idea of the magnitudes of the actual electrostatic forces to which the " surface ions " are subjected. For a field strength of 800,000 volts/cm., the pull on an ion in a moderately smooth filament surface is computed to vary from about 63×10^{-8} dynes to roughly twice that amount, depending on how far out the individual ion may be from the surface described by the remaining "surface ions." This force is of the magnitude of the force computed from the estimated yield stress for a tungsten wire at incandescence reduced to a single atom (yield stress ÷ cross-sectional surface density of atoms). This approximate coincidence, together with the failure to detect an effect of an electrostatic field on vaporization, does not necessarily indicate any error in supposition (1) or in the computations made, since, on the "amorphous phase theory" of the binding material between grains the yield stress may depend on the weak amorphous phase while the resistance to vaporization depends largely on the cohesive forces within the crystal. Moreover, vaporization takes place by atoms, whereas the yielding of a stressed wire takes place by layers or "en bloc." On the other hand, the approximate coincidence leads us to hope that, by increasing the field strength, or by a modification of conditions, a positive influence of electrostatic fields on vaporization may be found.

CLEVELAND, OHIO,
November, 1920.

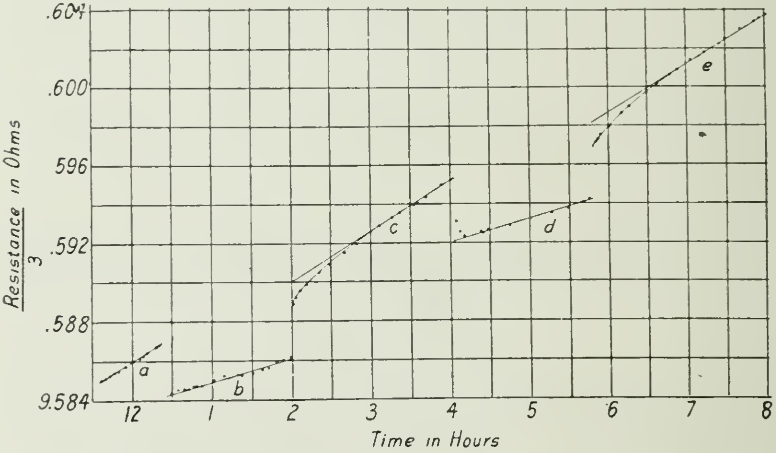
EFFECT OF STRONG ELECTROSTATIC FIELDS ON THE VAPORIZATION OF TUNGSTEN. II.

By A. G. Worthing and W. C. Baker.

THIS abstract covers work done in continuation of that reported on at the November meeting in Cleveland. The procedure, unchanged except in minor details, consists in noting the rate of increase in resistance of an incandescent filament in vacuo, first, when in a weak electrostatic field such as to prevent thermionic emission, and second, when in a strong field similarly directed. A difference in the two rates of increase is taken as evidence that vaporization is influenced by electrostatic fields.

In the work previously reported, a field strength of 800,000 volts/cm. at the surface of the filament, resulted in no appreciable change in the rate of increase of resistance with time. Since then improvements in the kenotrons, principally the reduction in filament diameter from 0.060 mm. to 0.020 mm., have resulted in considerably greater field strengths, the maximum being about 3.2×10^{-6} volts/cm.

The variation of resistance with time during a test, in which a field strength of 2.7×10^6 volts/cm. and a filament temperature of 2500° K were employed, is shown in the accompanying figure. The filament was operated throughout at 0.100,000 ampère. A steady temperature distribution was obtained after two hours of preliminary burning. Voltage readings were begun at 11 hr. 38 min. At 12 hr. 23 min. the strong electrostatic field was applied, at 2 hr. 0 min. it was removed, etc. With one exception, the variations shown are typical of those found in each case for field strengths above 1×10^6 volts/cm. Continued operation of the filament under each of the two conditions of burning led to a straight line relation between voltage and time, and hence also between filament resistance and time. Each change from a strong to a weak field caused a sudden increase in voltage readings, followed by a rather slow asymptotic change superposed upon the final straight line change with respect to time. Reverse changes, though less evident, occurred when the strong field was applied.



Effect of strong electrostatic fields on the vaporization of tungsten II.

A positive effect of the electrostatic field on the rate of vaporization is shown in the figure by (1) the change in slope from 2.55×10^{-3} ohms/hr. for the weak field to 1.15×10^{-3} ohms/hr. for the strong field and (2) the lateral shifts in the straight lines representing the resistance changes after prolonged burning in the weak field. These effects diminished with diminishing field strength in such a manner as to indicate the practical disappearance of the effects at somewhat less than a million volts per cm.

On the other hand, test with one kenotron—the one used in obtaining the data shown in the figure—with a field of 3.2×10^6 volts/cm. showed neither of the two positive indications noted above; even though, when the strong field was applied or removed, the sudden and the slow asymptotic changes were more evident than when the lower field strengths were employed.

Work on this problem is being continued.

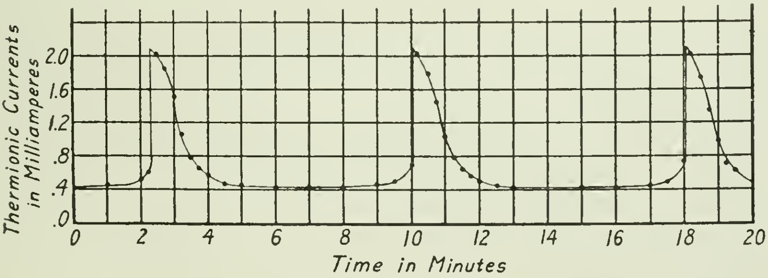
CLEVELAND, OHIO,
December, 1920.

PULSATING THERMIONIC DISCHARGES IN EVACUATED TUNGSTEN LAMPS.

By A. G. Worthing.

THE starting point of this investigation has been the observation of peculiar, periodic, automatic changes in brightness of a certain tungsten ribbon filament in an evacuated lamp bulb. Several other lamps were investigated only a few of which showed similar discharges, and none to the extent shown by the one in which the discovery was made.

All of the lamps tested contained a third insulated terminal by means of which thermionic discharges in the lamp could be measured. Simultaneous observations of thermionic currents and of filament brightnesses by means of an optical pyrometer showed conclusively that the original variations noted in the filament brightness were directly connected with changes in the thermionic discharges in the lamp. These discharges may take place either from the filament to the insulated terminal, or from one leg of the filament to the other.



Pulsating thermionic discharges.

The tungsten ribbon filament in the lamp tested was V-shaped, with sides about 2.5 cm. long and with an apex slightly truncated so as to give an approximately square surface 1 mm. on edge, which in the mounting faced the third terminal, also of tungsten. The lamp was evacuated in the ordinary manner.

In one test, a direct current of 8.2 ampères was used in heating the filament to a temperature of about 2280° K. The negative terminal of a 44-volt battery was connected to one of the leads to the ribbon filament through a voltmeter with 5000 ohms resistance; the positive terminal of the battery was connected to the insulated terminal in the bulb.

The thermionic currents represented by the voltmeter readings showed discharges of a pulsating character (see accompanying figure) in which without any alteration of conditions by the experimenter, the currents rose from a moderately steady minimum, at first slowly and then with great suddenness, to a maximum value at least 4.8 times the minimum value. The period of the discharge, eight minutes, was constant for nine successive intervals to within 4 per cent. Small characteristic variations in the form of the curves were repeated also.

Different temperatures of operation, different applied voltages and resistances in the voltmeter circuit, yielded discharges differing in period, minimum and maximum current values, and ratios of maximum to minimum current values. Temperatures beyond a certain value and resistances below a certain minimum in the thermionic current circuit, other conditions remaining unchanged, tended toward pulsations which gradually diminished in intensity and disappeared, leaving a steady thermionic discharge.

No definite explanation is offered for this action. However, the blue glow discharges which were obtainable in the lamps used would seem to indicate that it might be connected with the residual gases in the lamps.

CLEVELAND, OHIO,
November, 1920.

THE CURRENT TEMPERATURE RELATION FOR DIFFERENT PYROMETER FILAMENTS.

By W. E. Forsythe.

THE calibration of a disappearing filament optical pyrometer is a determination of a relation between the temperature of the standard source and the current through the pyrometer filament, when the latter is matched in brightness. For ease in reading temperatures against the standard, the current change for a particular temperature change should be as large as possible. It has often been stated that carbon pyrometer lamps were better than tungsten, because carbon at low temperatures gives a more open scale than the tungsten.

A test of this current temperature relation was made for a temperature range from 950° K to 1800° K. It was found that, if both the tungsten and the carbon pyrometer filaments were long enough so that the cooling due to end conductions were negligible, the ratios were about the same for the two.

The ratio of the currents for a hairpin tungsten filament, length of loop 12 cms., was 4.2 for a temperature range from 1828° K to 950° K; the ratio for a carbon hairpin loop 10 cms. long was 4.5 for the same temperature range. Both filaments were long enough so that the end effects could be neglected.

Development of Autochromes. (*Photographic Jl. of Am.*, April, 1921, p. 155.)—In spite of the many methods for color-photography that have been devised, the autochrome constitutes the simplest and most satisfactory in many lines, especially in photomicrography. The development of the plate was at first a tedious and troublesome process, and all the more unsatisfactory because of the tenderness of the film, which caused the loss of many a picture. Two features of the development were somewhat irritating; the prescription of a special chemical, " metoquinone," sometimes called " quinomet," and the use of an acid permanganate as an oxidizing agent. The latter is liable to form flocculent manganese dioxide, which deposits on the plate. The writer had a very pretty plate injured in this way. A solution of potassium dichromate and sulphuric acid is much better for oxidizing purposes. It can be prepared very strong, and diluted when used. It keeps indefinitely, and is cheaper than the permanganate solution. The special developer which figured in all the Lumière formula, was suspected by most photographers to be merely a mixture of our familiar dark-room twins, metol and hydroquinone, and this is now known to be the case.

Lumière Brothers have stated that instead of their " metoquinone," a mixture of metol and hydroquinone in the proportion of 10.5 parts of the former to 4.5 parts of the latter can be used. Victor Cremier states in "*Photo-Revue*" that the proportion of 7 parts of metol and 8 parts of hydroquinone gives excellent results. This is preferable, as metol is so much more costly than the other substance. Adopting Cremier's modification of a formula, given by Lumière Brothers, the following is a formula taken from a recent issue of the "*Photographische Chronik*":

Water	1000 c.c.
Metol	7 gm.
Hydroquinone	8 gm.
Sodium Sulphite, dry	100 gm.
Ammonia (sp. gr. 0.923)	32 c.c.
Potassium Bromide	6 gm.

For use, dilute with four volumes of water.

The following developer was proposed about the time that the autochrome came into use:

Water	1000 c.c.
Sodium Sulphite, dry	40 gm.
Metol	6.5 gm.
Hydroquinone	2 gm.
Hypo.	0.1 gm.
Ammonia (sp. gr. 0.880)	20 c.c.
Potassium Bromide	2.5 gm.

For use, dilute with an equal volume of water.

For some lines of work, especially photomicrography, the second development may be omitted. Given a good exposure and a good first development,the oxidizing agent is then applied until the silver deposit is completely removed. The plate is then washed and dried. The unchanged silver bromide will act as the opaque coating, upon which the correct color effect depends.

Striking effects can be obtained by the use of autochromes in photographing the colors produced by the transmission of polarized light through rock section.

Melting Point of Ammonium Sulphate.—James Kendall and Arthur W. Davidson of Columbia University (*Journ. Ind. and Eng. Chem.* 1921 xiii, 303–304) have found the melting point of *acid* ammonium sulphate to be 146.9° ± 0.5° C., and the melting point of *neutral* ammonium sulphate to be 513° ± 2° C. The extreme discrepancies in the literature concerning these melting points were found to be due essentially to the instablity of the neutral salt when heated in an open tube.

J. S. H.

NOTES FROM THE RESEARCH LABORATORY EASTMAN KODAK COMPANY.*

PHOTOMETRIC METHODS AND APPARATUS FOR THE STUDY OF COLLOIDS.[1]

By S. E. Sheppard and Felix A. Elliott.

[ABSTRACT.]

Two types of apparatus are described intended for the study of suspensions or any finely divided systems. The underlying principle of the apparatus is the formation of two beams of light from the same light source. One of these beams is passed through the sample to be tested while the other, after passing through a wedge which controls its intensity, is brought into contiguity with the first beam by means of a photometric cube, and an intensity match is made.

In the first type of the apparatus all elements and beams are in the same horizontal plane. This form is particularly adapted to the measurement of the turbidity or clarity of solutions.

The second type of the apparatus has the optical system in the vertical plane. The standard and unkown solutions are interposed in the two light beams and may be compared as to color, light scattering power, clarity and by means of these measurements phases changes and quantitative determinations of the concentration of either phase may be made. This second type of the apparatus is readily convertible into a colorimeter of the usual type, a nephelometer, a scatter photometer, a mircro-photometer and a dispersimeter.

The dispersimeter is in itself a new instrument and is intended to measure dispersity. Concretely this is illustrated by considering an etched steel surface of which it is desired to estimate the relative areas of the etched to unetched constituents. An image of this steel etching is observed along side of an image of some standard dispersity, such as a halftone screen. In this screen we know accurately the ration of black to white space. The image of the standard screen is now enlarged until its pattern matches that of the steel. By dividing the enlargement of the steel image by the magnification of the standard screen or pattern the dispersity is accurately specified. The instrument has many practical uses.

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* Communicated by the Director.

[1] *J. Amer. Chem. Soc.*, 43, 531, March, 1921, Communication No. 106, from the Research Laboratory of the Eastman Kodak Company.

Dissolved Gases in Glass. WASHBURN, FOOTITT & BUNTING. (*Bulletin No. 118*, Engineering Experiment Station, University of Illinois.)—One of the difficulties encountered in the manufacture of glass is the prevention of small gas bubbles in the finished product, which are technically known as "seed."

The occurrence of these bubbles is due to the process of manufacture and is practically unavoidable, to a small extent at least, with ordinary methods. While for many purposes, provided that the bubbles are not too large or too numerous, the matter is of minor importance, there are other cases where it is most desirable to have a glass absolutely free from seed.

The bulletin deals with certain experimental work carried on at the Engineering Experiment Station of the University of Illinois with the object of discovering, if possible, a method by which a glass free from this defect might be produced.

The experiments described are to be regarded as preliminary to a more extended investigation, but have already demonstrated that even apparently clear glass may contain a considerable quantity of dissolved gas, which is the factor instrumental in producing seed. In addition, as a result of the experimental work, a convenient apparatus for measuring and analyzing the dissolved gases was developed, and an improved type of vacuum furnace for the manufacture of gas-free glass, which it is believed is capable of commercial application, was constructed.

The Phosphate-Rock Industry.—The phosphate-rock industry in the United States in 1920, according to figures from all producers compiled early in April by the United States Geological Survey, made a record far surpassing that of any previous year. The quantity of phosphate rock mined and sold was 4,103,982 long tons, or nearly a million tons more than in the record year 1918. The total receipts from sales was $25,079,572, or more than twice as much as in any other year. The average price per ton for the entire output was $6.11, as compared with $5.10 in 1919.

Florida's output more than doubled, the quantity of land pebble phosphate increasing by more than one and one-half million tons. South Carolina produced 27 per cent. less than in 1919, but Tennessee increased her output 100,000 tons, or 18 per cent. A most notable feature of the year was an increase of 223 per cent. in the production in Idaho and Utah. The western output, most of which was made by Idaho, increased from 17,000 tons in 1919 to more than 55,000 tons in 1920.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES ON THE DIGESTIBILITY OF PROTEINS IN VITRO.

I. THE EFFECT OF COOKING ON THE DIGESTIBILITY OF PHASEOLIN.[1]

By Henry C. Waterman and Carl O. Johns.

[Abstract.]

Experiments to explain the findings of Johns and Finks[2] that phaseolin gave better results in feeding experiments after cooking than did the raw protein indicate that phaseolin is rendered more readily digestible by boiling with distilled water. Cooking for 5 minutes gave a delectable increase in digestibility, while cooking for ¾ hour was apparently sufficient to produce the maximum effect. It would seem therefore that the better results obtained after cooking may be considered to be due to an increase in digestibility.

STUDIES IN NURITION. V. THE NUTRITIVE VALUE OF SOY BEAN FLOUR AS A SUPPLEMENT TO WHEAT FLOUR.[3]

By Carl O. Johns and A. J. Finks.

[Abstract.]

Bread made with a mixture of 25 parts of soy bean flour and 75 parts of wheat flour contained a protein mixture and water soluble vitamines adequate for normal growth. A similar bread containing 15 parts of soy bean flour and 85 parts of wheat flour likewise furnished adequate proteins and water-soluble vitamines for normal growth.

These mixtures of the soy bean and wheat proteins were found two or three times more efficient than the proteins from wheat alone.

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* Communicated by the Chief of the Bureau.

[1] Published in *J. Biol. Chem.*, 1921, 46: 9.

[2] Published in *J. Biol. Chem.*, 1920, 41: 379.

[3] Published in *Am. J. Physiol.*, 1921, 55: 455.

THE USE OF EDESTIN IN DETERMINING THE PROTEOLYTIC ACTIVITY OF PEPSIN.[1]

By Joseph F. Brewster.

[ABSTRACT.]

THE United States Pharmacopœia method is the only official one in the United States for the assay of pepsin. This method is not proving satisfactory. Edestin, the protein of hempseed, has been used to supply the protein in clinical methods worked out by others for the determination of proteolytic activity, and since it is easily and cheaply prepared the author considers that it may advantageously be used in the assay of commercial pepsin.

Edestin is prepared by extracting nearly fat-free hempseed meal with 5 per cent. sodium chloride solution at 65°. The edestin, which separates on cooling the filtered extract, is recrystallized from the same medium. The nitrogen content of the washed and air-dried edestin is carefully determined, and this multiplied by 5.35 is adopted as giving the percentage of edestin in the preparation. From this the amount of preparation to supply a given amount of edestin is calculated.

For the assay a 1 per cent. solution of edestin in 0.1 N hydrochloric acid is placed in test tubes arranged in a constant temperature bath at 37.5° in increments of 0.25 cc., beginning with 0.25 cc. in tube 1. Tubes 4, 5, and 6 receive 1 cc. To the edestin solution is added 0.1 N hydrochloric acid in decrements of 0.25 cc., beginning with 0.75 cc. in tube 1, thus adjusting the volume in each tube to 1 cc. One cc. of 10 per cent. sodium chloride solution is added to each tube to precipitate the protein. This is followed by the addition of 1 cc. of a 1 per cent. solution of the pepsin to be tested in 0.05 N hydrochloric acid. The time from the beginning of the addition of pepsin until the protein is completely liquefied is noted. If the volume of subtrate is represented by s, and the time of digestion by t, then $\frac{t}{s}$ is nearly constant. It is better to adopt the mean $\frac{t}{s}$ for all the tubes as the constant. The comparison of the proteolytic activity of different pepsins resolves itself into a comparison of the constants thus obtained.

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[1] Published in *J. Biol Chem.*, 46 (1921) : 119.

NOTES FROM THE U. S. BUREAU OF MINES.*

UNDERGROUND CONDITIONS IN OIL FIELDS.

By A. W. Ambrose.

THE output of oil and gas in the United States is steadily declining. Coincident with this decline is a steadily increasing demand for petroleum and its products, and at present there are no commercial substitutes for lubricating oil. In order to obtain the highest efficiency in the production of oil, the operator should so organize his forces for development and production that he recovers every barrel of oil that can be recovered at a profit. This necessarily involves the use of economical and scientific methods of development and production, and the elimination of waste.

Bulletin 195 of the Bureau, recently issued, outlines methods for the practical application of engineering to underground problems in oil fields.

FLOTATION OF IDAHO ORES.

By Clarence A. Wright.

The United States Bureau of Mines in coöperation with the Idaho Bureau of Mines, the University of Idaho, and certain mining companies is investigating the applicability of differential flotation to the treatment of certain lead and zinc ores of the Coeur d'Alene region and other districts.

The chief metals produced from the ores of the Coeur d'Alene region are lead and zinc, with minor amounts of copper, silver and antimony. Where the minerals are finally disseminated, it is almost impossible to make clean lead and zinc products by the usual methods of gravity concentration, and fine grinding is essential.

Results of flotation tests on samples of mill feeds from a number of mills in this region indicate that the relatively fine slimes produced in the mills can be successfully treated by differential flotation, and this can be effected without any great changes in existing mills. Details of the tests are given in Bulletin 205, recently issued by the Bureau.

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* Communicated by the Director.

ANALYSIS OF SULPHUR FORMS IN COAL.

By Alfred R. Powell.

Methods for the analysis of total sulphur in coal have been in use for many years. Technically, a total sulphur determination is useful as indicating one of the factors that fix the value of particular coals for use under steam boilers, for general heating, and for the manufacture of coke and gas.

For certain purposes, however, it is desirable to know not only the total sulphur content, but also how the sulphur is combined in the coal and the exact amount of each form present. Such data are useful in indicating how much of the sulphur can be removed from the coal by washing processes, what effect the sulphur has on the heating value of the coal, how the varying sulphur forms—pyrite, sulphate, organic sulphur—behave during coking and gas making, and other facts of interest to coal technologists.

The writer, while working with S. W. Parr at the University of Illinois, had developed a method for determining sulphur forms that was applicable to Illinois coals. This method has been tested out in the Bureau of Mines laboratories, on coals from other districts, and has been found to be reliable and accurate. Certain modifications were developed to make the method more suitable to routine and rapid commercial analysis. Details of the procedure are given in Technical Paper 254.

GAUZES IN MINERS' FLAME SAFETY LAMPS.

By L. C. Ilsley.

The durability of the gauze used in miners' flame safety lamps, under the various conditions of temperature and other conditions that may affect the lamp, is obviously of the greatest importance. The bureau's specification in testing lamps for their suitability for use in gaseous mines has required steel or charcoal annealed iron wire. As the use of brass and copper gauze has frequently been advocated and in some instances actually used, the Bureau has conducted tests to determine the relative safety of such gauzes as compared with iron and steel. The results have not been deemed of such a nature as to justify changing the present specifications. Details of the tests are given in Technical Paper 228.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, May 18, 1921.)

Hall of the Franklin Institute,

Philadelphia, May 18, 1921.

Vice-President Mr. Coleman Sellers, Jr., *in the Chair.*

By consent, the reading of the minutes of the previous meeting was dispensed with.

The Chairman announced that the first business of the meeting would be the presentation of a Certificate of Honorary Membership to General John J. Pershing, General of the Armies of the United States, and recognized Dr. Harry F. Keller, who read the following resolution passed at the Stated Meeting of the Institute held March 16th last:

> "*Resolved,* That General John J. Pershing, General of the Armies of the United States, be elected to honorary membership in the Institute, in recognition of his signal success in the use of scientific and technical methods and means in modern warfare"

and presented General Pershing to the Chairman.

The Chairman then referred to the General's brilliant services rendered to our country and to mankind and handed him the Certificate of Honorary Membership. General Pershing expressed his thanks for the honor conferred upon him, and spoke appreciatively of the work of American Scientists and Technologists in general and especially of that of the members of The Franklin Institute in the world war.

The Chairman next announced that the annual presentation of The Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements would be made, and recognized Dr. Joseph S. Ames, who gave an account of the work of Professor Charles Fabry of the University of Paris, France, recently awarded The Franklin Medal in recognition of

> "His numerous and highly important contributions in the field of physical science, particularly the solution of optical and spectroscopical problems of fundamental importance."

His Excellency M. Jusserand, French Ambassador, was then presented to the Chairman and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute awarded to Professor Fabry. His Excellency conveyed the thanks of his government for the honors conferred upon his distinguished countryman.

Mr. W. C. L. Eglin was then recognized and described the work of Mr. Frank Julian Sprague, of New York City, who had also been awarded The Franklin Medal in recognition of

> "His many and fundamentally important inventions and achievements in the field of electrical engineering, notably his contributions to the development of the electric motor and its application to industrial purposes and in the art of electric traction, signally important in forming the basis of world-wide industries and promoting human welfare."

Mr. Sprague was then presented to the Chairman, and received from him The Franklin Medal, accompanying Certificate and Certificate of Honorary Membership in the Institute. Mr. Sprague expressed his thanks for the high honors conferred upon him.

The paper "Studies in the Field of Light Radiation" by Professor Charles Fabry was read by Dr. Joseph S. Ames, Professor of Physics, The Johns Hopkins University.

Mr. Sprague then read his paper "Electric Traction—A Review."

Adjourned.

R. B. OWENS,
Secretary.

(A full account of the meeting will appear in a later issue of the Journal.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 4, 1921.)

HALL OF THE INSTITUTE,
PHILADELPHIA, May 4, 1921.

MR. CHARLES W. MASLAND *in the Chair.*

The following reports were presented for final action:

No. 2676. Leading-in-Wire for Incandescent Lamps. The Elliott Cresson Medal to Dr. Byron E. Eldred, of New York.

No. 2772. Literature. The Howard N. Potts Medal to Dr. E. V. McCollum, of Baltimore, Maryland.

The following reports were presented for first reading:

No. 2741. Precision Thread Grinder. Dismissed without prejudice.

No. 2769. Variable Pressure Viscometer.

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A meeting was held in the Hall of the Institute, on Thursday evening, April 7, 1921, at 8 o'clock P.M., with Prof. Alexander E. Outerbridge, Jr., in the Chair. The minutes of the previous meeting were approved as published.

George Otis Smith, Ph.D., Sc.D., LL.D., Director of the U. S. Geological Survey, Department of the Interior, Washington, D. C., delivered an address on "Geology in Partnership with American Industry," in which the growth of the professions of industrial and engineering geologists was described, as well as their part in the development of American industries.

The communication was discussed by Professor Outerbridge, Doctors Chance and Smith, and others. A vote of thanks was extended to Doctor Smith; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary, pro tem.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 14, 1921, with Mr. George R. Henderson in the Chair.

Mr. N. W. Storer, General Engineer, The Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., presented a paper entitled, "The Characteristics of the Electric Locomotive." The speed and tractive effort characteristics of the different types of electric locomotives were discussed, and a comparison of the similar characteristics of steam locomotives was presented. Questions relating to speed control, regenerative braking and the advantages and limitations of the electric locomotive with respect to short time, heavy loading, mileage etc., were also discussed.

Mr. A. W. Gibbs, Chief Mechanical Engineer, Pennsylvania System, Philadelphia, and a member of the Institute's Board of Managers, presented a communication entitled, "Some Mechanical Characteristics of High-Speed, High-Power Locomotives." In this paper were discussed such questions as the mechanical applications of the electric power and the stability of both steam and electric locomotives as vehicles as determined in road tests on recording track.

Both communications were illustrated with lantern slides.

After a discussion the thanks of the meeting were extended to the speakers.

Adjourned.

R. B. OWENS,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 28, 1921, at 8 o'clock with Dr. George A. Hoadley in the Chair. The minutes of the previous meeting were read and approved.

C. A. Skinner, Ph.D., Chief of the Optical Division, Bureau of Standards, Washington, D. C., presented a communication on "The Polarimeter and Its Practical Applications." The development of polarimetric apparatus was traced, and the uses of such apparatus were described. The lecture was illustrated with experiments and lantern slides.

The paper was discussed; a vote of thanks was extended to Doctor Skinner; and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 11, 1921.)

NON-RESIDENT.

MR. GEORGE W. MCCLELLAND, 67 First Street, Troy, New York.
MR. ALFRED O. TATE, Cranston, Rhode Island.
MR. FREDERICK K. VREELAND, 90 West Street, New York City.

CHANGES OF ADDRESS.

MR. G. M. BASFORD, 17 East 42nd St., New York City.
DR. EDWIN M. CHANCE, 107 Surrey Ave., Ventnor, New Jersey.
MR. FRANCIS J. COLE, 3 Avon Road, Schenectady, New York.
MR. JAMES A. FLYNN, 3133 Camac Street, Philadelphia, Pennsylvania.
MR. J. K. M. HARRISON, Harrison & Company, Drexel Building, Philadelphia, Pennsylvania.
MR. MALCOLM R. MACLEAN, Haverford, Pennsylvania.
MR. J. V. MEIGS, 33 Clinton Street, Malden, Massachusetts.
MR. CARROLL B. NICHOLS, 1214 Widener Building, Philadelphia, Pennsylvania.
PROF. I. M. RAPP, R. D. 3, Phoenixville, Pennsylvania.
MR. JOHN B. RUMBOUGH, 328 South Center Street, Reno, Nevada.
MR. L. K. SILLCOX, Box 579, Herrick Road, Riverside, Illinois.
PROF. MONROE B. SNYDER, 111 Grand View Road, Ardmore, Pennsylvania.

NECROLOGY.

James S. Whitney, was born in Brownville, Jefferson County, New York, on December 2, 1830, and died in Philadelphia, March 19, 1921.

He came to Philadelphia in 1842, and in 1847 joined his father and brothers in the manufacture of chilled car wheels, a business which was continued for over half a century.

He was actively interested in civic and municipal affairs, and was for many years a member of the Board of Education of Philadelphia. He was a Life Member of the Institute.

Mr. Henry Spencer Blackmore, 1 West 34th Street, New York City.
Mr. Joseph C. Fraley, 1815 Land Title Building, Philadelphia, Pennsylvania.
Mr. Joseph B. Rohrman, Drexel Hill, Pennsylvania.
Mr. Lewis Seal, 217 Cooper Street, Camden, New Jersey.
Mr. William Smith, 1417 W. Dauphin Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

BROMLEY, H. A.—Paper and Its Constituents. 1920.
CARMAN, E. S.—Foundry Moulding Machines and Pattern Equipment. 1920.
CARR, H. W.—General Principles of Relativity. 1920.

COLVIN, F. H. and ETHAN VIALL.—United States Rifles and Machine Guns. 1917.

FALK, G. K.—The Chemistry of Enzyme Actions. 1920.

FISCHER, EMIL.—Introduction to the Preparation of Organic Compounds. 1917.

HALE, S. A.—The Coal Trade. 1920.

HUNZIKER, OTTO F.—Condensed Milk and Milk Powder. 1920.

JACKSON, DOUGLAS H.—Detail Design of Marine Screw Propellers. 1920.

JACKSON, D. C. and C. P.—Alternating Currents and Alternating Current Machinery. 1920.

PEELE, ROBERT.—Compressed Air Plant. 1920.

SEARLE, A. B.—Modern Brickmaking. 1920.

SOTHERN, J. W. M.—Oil Fuel Burning in Marine Practice. No date.

SUTERMEISTER, E.—Chemistry of Pulp and Paper Making. 1920.

THOMSEN, T. C.—The Practice of Lubrication. 1920.

WILLIAMS, K. P.—Dynamics of the Airplane. 1921.

GIFTS.

The Family Adviser; or a plain and modern practice of physic; calculated for the use of famlies who have not the advantages of a physician. . . . by Henry Wilkins, M.D. The fifth edition, to which is annexe/ Mr. Wesley's Primitive Physic, revised, 286 pages, 16mo., New York, Daniel Hitt and Thomas Ware, 1814. (From Mr. D. N. Ogden.)

Valuable Secrets Concerning Arts and Trades; or, approved directions, from the best artists for the various methods of engraving on brass, copper, or steel, of the composition of metals and varnishes. etc. . . . 240 pages, 12mo., Norwich, Thomas Hubbard, 1795. (From Mr. D. N. Ogden.)

Franklin, Benjamin, Life, Written by Himself. New York City, New York, 1824.

A Collection of the Familiar Letters and Miscellaneous Papers, now for the first time published. Boston, Massachusetts, 1833. (From Mr. J. A. P. Crisfield.)

Aldrich Pump Company, "Hydraulic Machinery." Allentown, Pennsylvania, 1920. (From the Company.)

American Arch Company, The Locomotive Heat Balance. New York City, New York, 1921. (From the Company.)

American District Steam Company, Bulletin No. 151, 152 and 153. New York City, New York, 1921. (From the Company.)

American International Corporation, Report of the President for 1921. New York City, New York, 1921. (From the Corporation.)

American Sugar Refining Company, Annual Report for 1920, New York City, New York, 1920. (From the Company.)

Amherst College, Catalogue of the College for 1920–1921. Amherst, Massachusetts, 1921. (From the College.)

Armstrong Brothers Tool Company, Catalogue B-20. Chicago, Illinois, 1920. (From the Company.)

Baker, J. T., Chemical Company, Catalogue of Baker's Analyzed Chemicals with Typical Analysis. Phillipsburg, New Jersey, 1920. (From the Company.)

Barber-Greene Company, Cost Data of Barber-Greene Methods. Aurora, Illinois, 1920. (From the Company.)

Brady, The James A., Foundry Company, "Twelve Fuel Facts About the Harrington Stoker." Chicago, Illinois, 1920. (From the Company.

Bristol Company, Catalogue No. 712. Waterbury, Connecticut, 1921. (From the Company.)

Burden Iron Company. Catalogue. Troy, New York, 1920. (From the Company.)

Canada Department of Mines, Annual Report for the Year 1919. Ottawa, Canada, 1920. (From the Department.)

Case, J. I., Threshing Machine Company, Case Kerosene Tractors and Grand Detour Plows and Case Power Farming Machinery. Racine, Wisconsin, 1920. (From the Company.)

Chase, Frank D., Incorporated, "Factories that Fit." Chicago, Illinois, 1921. (From the Corporation.)

Chicago Mill and Lumber Company, Booklet "Boxes." Chicago, Illinois, 1920. (From the Company.)

College of Physicians, Transactions, Vol. xli. Philadelphia, Penna., 1919. (From the Secretary.)

Columbian Bronze Corporation, "Propellers in a Nut Shell." New York City, New York, 1920. (From the Corporation.)

Connecticut State Board of Health and Bureau of Vital Statistics, Sixty-eighth and Sixty-ninth Registration Report for 1915–1916. Hartford, Connecticut, 1919. (From the Board.)

Cory, Chas., and Son, Incorporated, Bulletins Nos. 29A, 33–39A. New York City, New York, 1920. (From the Corporation.)

Cutler-Hammer Manufacturing Company, "For the Mine." Milwaukee, Wisconsin, 1920. (From the Company.)

Dartmouth College, The Catalogue 1920–1921. Hanover, New Hampshire, 1920. (From the College.)

Denison University, Annual Catalogue 1920–1921. Granville, Ohio, 1921. (From the University.)

Denver Fire Clay Company, Bulletin No. 251. Denver, Colorado, 1920. (From the Company.)

Edwards, O. M. Company, Incorporated, Catalogue No. W-19. Syracuse, New York, 1920. (From the Company.)

Electric Hoist Manufacturers' Association, "The Strong Arm of Industry." New York City, New York, 1920. (From the Association.)

Hagan Corporation, "Boiler Regulation." Pittsburgh, Pennsylvania, 1920. (From the Corporation.)

Harvard College Observatory, Annals, Vols. 81, pt. 5; 83, pt. 5; 95. Cambridge, Massachusetts, 1921. (From the Director.)

Institution of Civil Engineers, Minutes of Proceedings. Vol. ccvii. London, 1920. (From the Institution.)

Institution of Engineers and Shipbuilders of Scotland, Transactions Vols. lxii and lxiii, 1918–1920. Glasgow. (From the Institution.)

International Nickel Company, Monel Metal. New York City, New York, 1920. (From the Company.)

Kelly, William E., Electricity the Burden Bearer. Chicago, Illinois, 1920. (From the Author.)

Library of Congress, A List of Geographical Atlases, Vol. iv. Washington, D. C., 1920. (From the Library.)

Mason Regulator Company, The Mason Book. Boston, Massachusetts, 1920. (From the Company.)

Massachusetts State Department of Health, Fifth Annual Report. Boston, Massachusetts, 1920. (From the Department.)

McCrosky Tool Corporation, Catalogue No. 8. Meadville, Pennsylvania, 1921. (From the Corporation.)

Mica Insulator Company, Catalogue No. 85. New York City, New York, 1921. (From the Company.)

New South Wales Water Conservation and Irrigation Commission, Report for the Year ended June 30, 1920. Sydney, Australia, 1920. (From the Director.)

Niles–Bement–Pond–Company, "Maag Gears." New York City, New York, 1920. (From the Company.)

Northern Engineering Works, Catalogue No. 28. Detroit, Michigan, 1920 (From the Works.)

Ohio Brass Company, Catalogue No. 18. Mansfield, Ohio, 1921. (From the Company.)

Parke, Davis and Company, Collected Papers from the Research Laboratory, Detroit, Michigan, 1920. (From the Director.)

Pennsylvania Electric Association, Proceedings of the Eighth, Ninth, Tenth, and Eleventh Annual Conventions, 1915–1918. Harrisburg, Pennsylvania. (From Mr. H. M. Stine, Secretary.)

Revolvator Company, Booklet, The Revolvator. Jersey City, New Jersey, 1920. (From the Company.)

Roberts and Schaefer Company, Bulletin Nos. 39–40. Chicago, Illinois, 1920. (From the Company.)

Slosson Edwin E., Creative Chemistry. New York City, New York, 1920. (From the Chemical Foundation.)

Society of Engineers, Transactions for 1920. London, England, 1920. (From the Society.)

South Australia Director of Mines and Government Geologist, Annual Report for 1919. Adelaide, South Australia, 1920. (From the Director.)

Standard Scientific Company, Suggestions for Laboratory Exercises in Optics. New York City, New York, 1921. (From the Company.)

Stanford University, Report Upon a Collection of Coccidæ from Lower California, Stanford University, California, 1921. (From the University.)

Stevens Institute of Technology, Annual Catalogue for 1921–22. Hoboken, New Jersey 1921. (From the Institute.)

Sturtevant, B. F. Company, Catalogue No. 276. Boston, Massachusetts, 1920. (From the Company.)

Sweet's Catalogue Service, Incorporated, Sweet's Engineering Catalogue, Seventh Annual Edition. New York City, New York, 1921. (From the Corporation.)

United States Naval Observatory, American Ephemeris for 1923 and Publication Vol. ix, Part 1. Washington, D. C., 1921. (From the Observatory.)

University of Pennsylvania, Catalogue 1920–1921. Philadelphia, Pennsylvania, 1921. (From the University.)

University State of New York, 14th Annual Report, Vol. iii. Albany, New York, 1920. (From the University.)

University of Virginia, Catalogue 1920-21. Charlottesville, Virginia, 1921. (From the University.)

Vanderbilt University, Register 1920–1921. Nashville, Tennessee, 1921. (From the University.)

Vogt, Henry, Machine Company, Bulletin No. 5, Louisville, Kentucky, 1920. (From the Company.)

Vulcan Crucible Steel Company, "Vulcan Tool Steels" Catalogue. Aliquippa, Pennsylvania, 1921. (From the Company.)

Western Australian Institution of Engineers, Proceedings, Vol. vii, viii, ix, and x. Perth, Western Australia, 1920. (From the Institution.)

Western Machine Tool Works, Catalogue No. 21. Holland, Michigan, 1921. (From the Works.)

Western Reserve University, Catalogue 1920–1921. Cleveland Ohio, 1921. (From the University.)

Wing, J. L., Manufacturing Company, "Wing Turbine Blower." New York City, New York, 1920. (From the Company.)

BOOK NOTICES.

International Association of Chemical Engineers. Proceedings of the third session of the Council held at Solvay Institute, Leopold Park, Brussels, 1913.

Though relating to actions taken before the great war, and representing international amities that have been broken by recent events, this pamphlet has considerable interest, as an attempt to establish greater uniformity in chemical and physical notation and nomenclature. A conference of certain portions of the old organization was held in Rome in June, 1920, at which further efforts were made towards uniformity. The principal point in the present circulation of the pamphlet is to invite action on the unification of the symbols in physical chemistry, a list of which, with comments, is given. In the session of 1913, steps were taken towards unification of the abbreviations of the names of Journals devoted to chemistry and allied branches, and, among other matters, William Ostwald urged the adoption of Ido (a modified Esperanto) as an international language, but his suggestion does not appear to have been taken up. Even in the brief summaries of the discussions, it is painfully evident that a systematic unification of the several systems of nomenclature and notation in the physical and chemical sciences will be a very difficult task, and the outlook for even moderate reform is not encouraging.

Henry Leffmann.

LEHRBUCH DER FARBENCHEMIE, EINSCHLIESSLICH DER GEWINNUNG UND VERARBEITUNG DES TEERS, SOWIE DER METHODEN ZUR DARSTELLUNG DER VOR- UND ZWISCHENPRODUKTE. By Dr. Hans Th. Bucherer, Ordinary Professor (retired) in the Dresden Technical High School, and instructor in the Berlin Technical High School. Second revised edition xi—580 pages, contents, index and bibliography. Leipzig, Otto Spamer. $8.40, in paper; $9.10, bound.

In this excellently printed volume we have a most comprehensive presentation of the intricate and extensive chemistry of those derivatives of tar that are of importance in the manufacture of the colors. So great is the amount of data presented that the reviewer scarcely knows where to begin. Some idea of the material may be gained by a summary of the table of contents. The work is divided into three main sections or chapters. The first, comprising sixty-seven pages, describes the tar from bituminous coal, its production and its preliminary treatment. The second section describes the intermediates, and comprises one hundred and eighty-nine pages. The third section, comprising three hundred and twenty-five pages, is the specific description of the artificial colors and a sub-section of fifty-nine pages on the natural colors. The latter are of very ancient and wide-spread use; mostly derived from vegetable sources, but one famous color, the Tyrian purple, especially characteristic of royalty was obtained from a species of shell fish. It is stated in this book that this color has been found to be analogous to indigo. In connection with the description of the "vat-dyes," of which indigo is the most important representative, and which have figured so largely in the recent discussions on tariff legislation regarding coal-tar products, it is worth while to summarize some statistics concerning indigo production. The struggle for production of synthetic colors, identical or equivalent to the natural forms, began early in the development of the coal tar industry. The first brilliant success was with alizarin. This, originally, entirely derived from the madder plant, was synthetized in 1868 by Graebe and Liebermann, and the process much improved by Caro in the succeeding year. Before long the artificial product had completely displayed the natural one. The great importance of indigo, and the knowledge that its principal coloring matter is analogous to tar products (in fact, anilin derives its name from the specific name of one of the indigo yielding plants, having been obtained among the products of the destructive distillation of that color) suggested research. It was in 1895, that the *Badische Anilin und Soda Fabrik* began the manufacture of the color in competition with the natural product. It was about this time that the late Raphael Meldola, in London, warned the English indigo-growers, who were the principal producers, that German competition was likely to interfere with their market, but they gave no special heed to his words. The early German enterprise was not very successful, but the procedures were constantly improved, until at the opening of the great war, the bulk of indigo used was " made in Germany." The statistics are informing. In 1895 the importation of indigo into Germany was valued at Mk. 21,500,000; by 1913, the importations had fallen to a mere trifle. The exports of the color from Germany were negligible in the latter years of the 19th century, but by 1913 had acquired a volume valued at Mk. 55,000,000. The production in India fell off steadily until the outbreak of the war, which, of course, cut off the German supply, and redeveloped the orginal industry, but towards the ending of the war a relaxation of the activity of the India fields set in. This is ascribed to the great increase of the difficulties of sea-borne traffic, in consequence of the activity of submarines. The author adds the comment, "The outlook for natural product in competition with the synthetic is not very rosy; notwithstanding the labors of English chemists, here, as in other cases, the German inventive genius and intrepid spirit will determine the victory." In Germany the price of the color fell from about Mk. 16 in 1895, to less than Mk. 6 in 1904. Much of this decrease was due to the competition between the two great producers, the BASF and the Hoechst works. This condition was eliminated by an agreement between the two firms, and the price was held at Mk. 7.50. The reduction accomplished, as compared with the earlier years, gave rise to a much increased use of the color. Unexpectedly in very recent time, it has been found that a treatment of indigo blue with benzoyl chloride in presence of copper-dust effects a change to a new color—indigo yellow—the composition of which is yet not clearly ascertained. This permits of the production of a fine green on both wool and cotton, when associated with indigo.

It is evident from the above selections that the work is a very comprehensive and detailed statement of all the important chemistry of the coal-tar colors. All the colors are explained as to their production, their composition being shown by structural formulas, of which there are many hundreds in the work.

The American reader will be a good deal interested in the evidence afforded by the book as to Germany's ability to recover the old control of this industry. A quotation given above shows the feeling in regard to the English indigo industry, but that is a competition between a natural and an artificial product. What is the outlook for the establishment of independent synthetic color industries in the other great nations? The question is a live one, not only on account of the color-manufacture proper, but because it is now recognized that the principal munitions of war—high explosives and poisonous gases—are largely produced by comparatively simple modifications of the methods employed in color manufacture. This turn-over in a short time from one form of procedure to the other cannot be accomplished unless the given nation has already developed large and efficient plants for carrying out all the operations with tar. Even these will not be of use, unless there is high technical skill and originality in the application of existing knowledge to the problems as they arise.

The reviewer not unnaturally institutes a comparison between the book in hand and that of Dr. Lange, reviewed a few months ago. Both relate to the tar industries, but the older book was limited to the intermediates. It was particularly commendable for the vividness with which each item was presented so much so that one of the items was reproduced as it is in the book. The book now under consideration does not follow Lange's method, but uses side-notes very liberally, which serve a good purpose and guide the user of the work to the place desired. It is a question why Dr. Bucherer has deemed it necessary to give with many of the ring formulas the supposititious double bonding. Kekulé, in his original paper, gave the plain hexagon as standing for benzene, and while the particular distribution of the double bonding has been a matter of much discussion in theoretical chemistry, there seems to be no reason for considering that phase in such a work as this. It is to be regretted that the German chemists still adhere to the unscientific terms "benzol," "toluol" and similar titles, when the world at large has adopted the "ene" termination, and limited "ol" to alcoholic structure. There is an extensive classified bibliography, but it seems that it would have been better to give the references at the point of which the information is stated, giving the whole list of references in their numerical order at the close. There is an excellent index.

The first fifty pages are taken up with historical and statistical matter. The early history of the coal-tar industry is not very creditable to England and France, for although the first steps in the utilization of the tar were made in the former country, the leading men of both failed to appreciate the possibilities of the industry, and even cheapened the value of the work being done in Germany. On page 7, Dr. Bucherer speaks briefly, in a foot-note of the probable duration of the world's coal supply. Such a speculation might be left unnoticed, as cases of this nature are of little or no value. The introduction of new sources of power may limit the use of coal, and many coal-fields may be found at present unsuspected. The statements in the foot-note, however, deserve a little more careful attention, for the author states that the coal-supply of Germany will last three thousand years, that of England only seven hundred years, and the North American supply only one thousand seven hundred years. The Coal deposits will, therefore, he says, be exhausted sooner in England and in the United States than in Germany. There seems to be a sinister meaning in this sentence, and the reply may appropriately be that even if true, seven centuries is a good while to wait for "Der Tag."

HENRY LEFFMANN.

ON THE DIFFUSION OF LIGHT BY THE MOLECULES OF TRANSPARENT GASES. Jean Cabannes. A Thesis Presented to the Faculty of Sciences, University of Paris, June, 1920. 149 pages, 8vo.

On one occasion when Lord Kelvin was presiding at a session of the Physics Section of the British Association for the Advancement of Science an auditor noted how he reconciled truthfulness with tact in his remarks at the close of the papers presented. When a genuinely valuable paper had been read the great physicist said in effect something about "this important contribution to an interesting subject," but, on the other hand, after a paper of mediocre value he would speak of "this interesting contribution to an important subject." To the thesis of M. Cabannes both adjectives "interesting" and "important" are fitting. The work is valuable because it materially increases our knowledge of the diffusion of light from the sky and throughout it is distinguished by the lucidity of presentation and symmetry of arrangement so characteristic of the Gallic scientists.

In the historical introduction the author sketches the attempts made in the second half of the nineteenth century to explain the blue of the sky from the supposititious water bubbles of Clausius onward through suggestions of fluoresence and selective absorption to a fixing of belief about 1900 upon diffusion by small particles as the real cause. In 1899 Lord Rayleigh advanced the proposition that the small particles concerned are none other than the molecules of the air. This is, of course, in direct contradiction to Tyndall's experiment showing, as he thought, air without floating particles to be "optically empty." This hypothesis soon found confirmation in the observations of Abbot and Fowle on Mt. Wilson, 1910–1911, from which it was deduced that the number of diffusing centres equaled the number of gaseous molecules. Any observations made on light from the sky are complicated by the fact that each point diffuses not alone the light from the sun, but also that coming from other points of the sky and from the earth as well. In 1913, M. Cabannes turned to the study of the phenomena in the laboratory and early in 1915 made known the first experimental proof that gas molecules really do diffuse light. Since that time others have reached the same conclusion.

In Part I a discussion of the theory of the diffusion of light by particles whose diameters are small in comparison with the wave-length is presented. According to the theory elaborated by Lord Rayleigh in 1871, the intensity of the diffused light is inversely proportional to the fourth power of the wave-length. Thus when the sunlight passes through the air the waves of shortest length are those chiefly diffused—in other words, the blue light is diffused laterally while the red and yellow, suffering less diffusion, pass through with less change in intensity. The English peer assumed that the air molecules are spherical, and from this it followed that the light diffused at right angles to the incident beam should be completely plane polarized. Experiment, however, shows that this is not the case. For this reason the author develops the theory for gas molecules not spherical but ellipsoidal in shape, no two axes being of the same length. From his experimental results for air interpreted by his theory comes a value for the number of molecules in a cubic centimeter of gas under standard conditions equal to 2.92×10^{-19} (Millikan obtained 2.709; Rutherford, 2.78; Perrin, 3.06) and for Avogadro's Constant, 65.4×10^{22} (Millikan, 60.7; Rutherford, 62.3; Perrin, 68.5).

Part II is devoted to a discussion of the observations of Abbot and Fowle, which confirm the prediction of Rayleigh that outside of bonds of selective absorption, the intensity of diffused light is as the reciprocal of the fourth power of the wave-length. Minimal values for the constants just mentioned are derived, viz. 2.92×10^{19} and 6.45×10^{23}, respectively.

In Part III, occupying by far the largest portion of the entire 149 pages, the experimental work of the author is described. A beam of light was sent through a mass of gas filtered to free it from foreign particles. The light coming at right angles from the path of the beam in the gas fell on a photographic plate, where the density of the image could be studied at leisure. From the lengthy series of experiments, carefully devised and protected from error, a number of important conclusions are drawn.

1. A transparent gas illuminated by a beam of light emits in turn light in all directions. Argon, hydrogen, oxygen, nitrogen and carbon dioxide were used, as well as air. The light from hydrogen was very faint, as is seen from the reproduction of the photographic imprint, while that from carbon dioxide was two or three times as strong as the light from air and ten times as strong as that emitted by hydrogen.

2. The radiation emitted laterally by the illuminated gas is composed of the same radiations as the primary beam. Of course the relative intensities of various wave-lengths are different as a result of the inverse fourth-power law. No trace of fluorescence was detected.

3. In the light diffused by a gas the intensity of any wave-length depends solely upon the intensity of that wave-length in the incident radiation and not on the spectral composition of the incident light.

4. The plane polarization of light at right angles to the incident ray is not complete in general and the Fresnel vibration is perpendicular to the plane containing the incident and diffused ray. The gas molecules appear in consequence to be not spherical.

5. When the incident ray passes through a vacuum all trace of the laterally diffused light vanishes.

6. The quantity of energy diffused by a gas under a certain pressure is a constant characteristic of the gas.

7. The quantity of energy laterally diffused by a gas is proportional to the pressure of the gas.

8. The light emitted laterally by argon is totally polarized. It is therefore admissible to assume that the argon molecule is spherical. Then applying Rayleigh's theory the value of Avogadro's Constant comes out 6.9×10^{23}.

The author is to be congratulated on the completion of this laborious research so long interrupted by the war.

GEORGE F. STRADLING.

RECOVERY OF NITRATE FROM CHILIAN CALICHE, CONTAINING A VOCABULARY OF TERMS, AN ACCOUNT OF THE SHANKS SYSTEM, WITH A CRITICISM OF ITS FUNDAMENTAL FEATURES AND A DESCRIPTION OF A NEW PROCESS. By A. W. Allen, M.A., Chemical and Metallurgical Engineer. xvi–48 pages, index and diagrams, 12mo. London, Charles Griffin & Company, Ltd.; Philadelphia, J. B. Lippincott Company, 1921.

Caliche is the crude sodium nitrate found in the Chilian deposits, quite variable in composition. The book in hand is a discussion of the processes adapted to the refining of the raw material, and the subject matter, therefore, has little interest for those not engaged in this special work. The extraction of sodium nitrate from this deposit began in the early part of the nineteenth century, the area then being under the control of Peru. At this early period, the caliche contained on an average about 75 per cent. of sodium nitrate, but the richness has been steadily diminishing, and the cruder procedures of the older time are not profitably applicable. The author presents the difficulties of the method generally in use, and offers an improved process of his own invention. The book is a valuable contribution to a process of mining which is practically unique and which has had a profound influence on the world's history in the last hundred years. As has happened with many other deposits of valuable mineral, much material has been thrown on the dump because extraction did not pay, but according to Mr. Allen, many millions of tons of caliche or residues rejected for such reasons are available if improved methods are applied. A valuable feature of the book is the vocabulary of terms relating to the subject. The question of the future of the nitrate beds is especially important in view of the progress that has been made in nitrogen fixation which may ultimately render the greater nations independent of these deposits.

HENRY LEFFMANN.

BIBLIOTHECA CHEMICO-MATHEMATICA. A catalogue of works in many tongues, on Exact and Applied Science. With a subject index. Compiled and annotated by H. Z. and H. C. S. In two volumes, having a total of 964 pages, with 127 plates, having 247 portraits and fac-similes, 8vo. London, Henry Sotheran & Co., 1921. £3.3 shillings net.

Although having the general appearance of an extra illustrated book catalogue, these two attractive volumes are really a bibliography of literature, past and present, relating to the physical sciences. The very numerous well-executed fac-similes give the reader an idea of the character of the books of the centuries immediately following the introduction of the art of printing. The identity of H. Z. is told in the preface. He is Heinrich Zeitlinger, of Linz, who is described as an "equal well-wisher of learning and of England" (Linz is in Austria, on the Danube). The identity of H. C. S. is not specifically disclosed but it does not need Sherlock Holmes to tell us that it is the present head of the house, Henry Cecil Sotheran. Why the initials should be used instead of the full names is a puzzle. Perhaps it is intended to be in keeping with earlier customs, as when a play was entered at Stationers' Hall as published by T. C. for W. S.

While not a complete bibliography of the literature, inasmuch as it represents only those works that the firm has for sale, the number of books noticed is very large and from them could be selected a good library of the early publications in the sciences included in the scope of the book. Almost all of the entries are accompanied by notes and comments, often quite interesting. The prices quoted do not seem high in comparison with those that usually obtain in the sale of private collections, but presumably "first editions" of scientists and mathematicians are not as much sought for as in other classes of literature. The illustrations are all well made and add greatly to the value and interest of the book. A mistake in one of the notes should be pointed out. It is stated that Ampère's name "is immortalized in electrical science as the unit of electromotive force." The ampère is the unit of current; that of electromotive force is the volt.

The classification in the main body of the work is alphabetically by authors, but the publisher has placed scientists under much obligation by an elaborate classification index by subjects, so that one interested in a particular line of science can find with but little trouble the works relating to it. The list is not confined to early books; comparatively modern editions and well-known contemporary publications are listed to a limited extent, but the real attractiveness of the catalogue is the books of the earlier period, and the many fac-similes of their pages. A number of very excellent portraits are included. That of Thomas Young is especially worthy of mention as a specimen of photogravure and printing.

The mechanical execution of the book is first class: good paper, good printing and good binding.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 93, Properties of Aerofoil Sections, 83 pages, diagrams, quarto. Washington, Government Printing Office, 1921. The object of this report is to bring together the investigations of the various aerodynamic laboratories of this country and Europe upon the subject of aerofoils suitable for use as lifting or control surfaces on aircraft. The data have been so arranged as to be of most use to designing engineers and for purposes of general reference.

The absolute system of coefficients has been used, since it is thought by the Committee that this system is the one most suited for international use, and yet is one for which a desired transformation can be easily made. For this purpose a set of transformation constants is included in this report.

Each aerofoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent. of the chord using as datum the line shown on the curves. The shape of the section is also shown with reasonable accuracy to enable one to more clearly visualize the section under consideration together with its characteristics. The more accurately to obtain the dimensions of the profile of each section, a separate data sheet for each section has been included, which gives an additional decimal place for the greater portion of the ordinates.

Report No. 100, Accelerometer Design, by F. H. Norton and Edward P. Warner. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

In connection with the development of an accelerometer for measuring the loads on airplanes in free flight a study of the theory of such instruments has been made, and the results of this study are summarized in this report. A portion of the analysis deals particularly with the sources of error and with the limitations placed on the location of the instrument in the airplane. The discussion of the dynamics of the accelerometer includes a study of its theoretical motions and of the way in which they are affected by the natural period of vibration and by the damping, together with a report of some experiments on the effects of forced vibrations on the record.

Report No. 102, performance of a Liberty 12 Airplane Engine, by S. W.

Sparrow and H. S. White. 20 pages, illustrations, quarto. Washington, Government Printing Office, 1921.

In coöperation with the Engineering Division of the Air Service of the United States Army, a Liberty 12 engine has been tested at the Bureau of Standards. The program of tests was planned to yield that information considered most important in determining the value of the engine for aviation. Full power runs were made at the ground at 25,000 feet, and at several intermediate altitudes. To determine the mechanical efficiency of the engine friction horse-power was measured at the ground and at 15,000 feet. As a basis for predicting engine performance with a propeller, a series of tests were made in which the dynamometer load and engine throttle were adjusted at each speed to simulate the engine load which would be imposed at that speed by a propeller operating under normal full load at 1,700 r.p.m.

Among the quantities calculated from the test measurements are: Brake horsepower; brake mean effective pressure; fuel consumption; mixture ratio; mechanical, thermal, and volumetric efficiency; and the percentage of heat in the fuel appearing in the jacket water and in the exhaust. Jacket water temperature, oil temperature, manifold pressure, etc., are recorded to show the conditions under which the test was made.

The provision on the carburetor for adjusting the mixture ratio is shown to be inadequate at altitudes above 15,000 feet. Improving the mechanical efficiency of the engine and making such changes as will prevent the present decrease of volumetric efficiency with increase of altitude are suggested as two possibilities of improving the altitude performance of the engine.

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Coke-oven and By-product Works Chemistry, by Thos. Biddulph Smith, F.C.S. 180 pages, illustrations, plates, diagrams, 8vo. London, Charles Griffin & Company, Limited; Philadelphia, J. B. Lippincott Company, 1921.

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